Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2003/045 | **Document de recherche 2003//045**

Not to be cited without Permission of the authors * | Ne pas citer sans autorisation des auteurs *

Stock Structure of Pollock in NAFO Divs. 4VWX5Zc.

Structure du stock de goberge des divisions 4VWX5Zc de l'OPANO.

John D. Neilson[1]
Peter Perley[1]
Erin H. Carruthers[1]
Wayne Stobo[2]
Donald Clark[1]

Biological Station, St. Andrews, New Brunswick, Canada E5B 3G7
Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2
National Marine Fisheries Service, Woods Hole, MA, USA 02

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

This document is available on the Internet at:

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883
© Her Majesty the Queen in Right of Canada, 2003
© Sa majesté la Reine, Chef du Canada, 2003

Canada

ABSTRACT

The stock structure of pollock (*Pollachius virens*) in the Northwest Atlantic was examined using information from a variety of sources including the commercial fishery, research vessel surveys of various stages of the life history, population parameters, meristic and morphometric data and mark-recapture information. It was concluded that there was sufficient information to suggest a division of the current management unit (NAFO Divs. 4VWX5Zc) into an eastern (4VW) and a western (4X5Zc) component. The current eastern and northern boundaries with NAFO Divs. 4T and 3Ps appear appropriate and should be retained. The boundary of the stock to the south in SA 5 appears less clear, however. The suggestion that the International Boundary form the limit of the management unit is based more on operational considerations rather than considerations of stock distribution.

RÉSUMÉ

La structure du stock de goberge (*Pollachius virens*) de l'Atlantique nord-ouest a été examinée à la lumière de renseignements provenant de plusieurs sources, incluant la pêche commerciale, des relevés de navire de recherche sur les divers stades du cycle de vie, des paramètres de population, des données méristiques et morphométriques ainsi que des données sur la recapture d'individus étiquetés. On conclut qu'il est justifié de diviser l'unité de gestion actuelle (divisions 4VWX5Zc de l'OPANO) en un secteur est (4VW) et un secteur ouest (4X5Zc). Les limites est et nord actuelles de la division 4T et de la sous-division 3Ps semblent appropriées et ne devraient pas être modifiées. La limite sud du stock dans la sous-zone 5 semble toutefois moins claire. La suggestion à l'effet que la frontière internationale constitue la limite de l'unité de gestion repose davantage sur des considérations d'ordre opérationnel que sur la distribution réelle du stock.

INTRODUCTION

For Canadian management purposes, the southernmost limit of the pollock (*Pollachius virens*) stock is considered to include those fish in the Canadian portion of Georges Bank and the Gulf of Maine. The management unit extends north to the Laurentian Channel (NAFO Divs 4VWX and 5Zc, Fig. 1). In comparison with other groundfish resources in the area, the Canadian management unit for pollock is large. Cod and haddock, as examples, are each managed as three discrete units over the same geographic limits as the pollock resource. If the management unit for pollock does not reflect the stock complexity of the resource appropriately, there is potential for over-exploitation of less productive components, or unrealized opportunities for harvesting more productive components. Stephenson (1999) further points out that failure to recognize or to account for complex stock structure could result in a loss of biological diversity, with unknown ecological consequences. As part of a "Framework Assessment" of pollock in 2003, all information relevant to stock structure was reviewed and the suitability of the current management unit was assessed. This document summarizes the information considered and the decisions reached.

The initial management unit for the pollock resource was established by the International Commission of the North Atlantic Fisheries (ANON., 1973), and included Division 4X and Subarea 5 (includes the Gulf of Maine and Georges Bank area) (Fig. 1). At the time, it was noted that the stock structure was not well understood. In 1974, as a precautionary measure to reduce the potential for misreporting, ICNAF considered it prudent to extend the management unit and treat pollock on the Scotian Shelf and the Gulf of Maine as a single stock. Thus, the management unit was enlarged to include Divisions 4V and 4W. After the establishment of the International Maritime Boundary in the Gulf of Maine area between Canada and USA in 1984, Canada reviewed the stock structure of marine resources in the area (Bowen 1987), including information on meristics, morphometrics, genetics and preliminary analyses of the available mark-recapture studies. It was concluded that the amount of transboundary movement was not sufficient to seriously affect stock conservation benefits if Canada undertook unilateral management actions within its own waters.

The USA view on stock structure was that pollock on the Scotian Shelf and Subarea 5 belong to a single unit stock (Clark et al. 1976). More recently, Mayo et al. (1989) reviewed distributional information, meristics

and morphometrics, and genetic studies, concluding that the available information did not allow them to refute the hypothesis of a single unit stock throughout Div. 4WX and Subareas 5 and 6.

Gulland (1983) identified five types of information useful in assessing stock structure. He argued that a discontinuous geographic distribution of fishing (1) could suggest a gap in the distribution of fish, which may correspond to a separation of stocks. Such information could also be obtained from fishery independent means, such as research vessel surveys. Information on spawning areas (2) is critical, since genetic separation of stocks requires a clear separation of spawning components, even if such fish mix at a later stage. Gulland considered that values of population parameters (3) may provide insight if there stock differences, citing parameters such as growth rate and mortality as examples. He noted that morphological or physiological characteristics that are genetically determined (4) can provide clear evidence that two groups are distinct, but genetic separation can, in principle exist without this being evident in the characteristics examined. Moreover, the effects of environmental variables on morphological or physiological characteristics can render the interpretation of variability difficult. Lastly, Gulland noted that tagging (5) can, in principal, provide the clearest evidence of stock separation or otherwise.

This document is intended to provide a comprehensive summary of available information relevant to a discussion of pollock stock structure in Canadian Maritimes waters. For the purposes of this study, we used the definition of Booke (1981) to define the term "stock": as a population of fish that maintains itself over time in a particular area. From the perspective of fisheries management, Gulland (1983) stated that the definition of stock is an operational matter. That is, a group of organisms can be treated as a stock if possible differences within the group and interchanges with other groups can be ignored without making fisheries management conclusions invalid. We evaluated the available data that fall within Gulland's five categories of information useful for the assessment of pollock stock structure. The data are then summarized and synthesized, and the authors' recommendations presented.

Information Available for Stock Structure Decisions

Commercial Fishery Distribution and Timing

If discrete areas of pollock distribution or differences in timing can be identified from fishery sources, these may be indicative of distinct populations. Such information is not conclusive, but could be investigated further.

Vladykov (1932, unpublished ms) described the pollock resource in the Bay of Fundy and the stock origins. Data available during this early period included landings information from 1917 on, and showed that pollock were landed all along the coast of Nova Scotia and southwest New Brunswick. The three areas that traditionally sustained the largest pollock fisheries before the advent of otter trawling were Charlotte County, Digby County and Halifax County. On the basis of fishery timing, he considered that pollock on the New Brunswick side of the Bay of Fundy probably were the same fish that supported the Gloucester, MA fishery. This inference was made from an inspection of the monthly pattern of landings from the two areas (Fig. 2). Vladykov also commented that fish from the Nova Scotia side of the Bay of Fundy could be of different racial origin than those from the New Brunswick side, based on the different patterns of fishery landings on both sides of the Bay.

Steele (1963) examined later fisheries data, and consistent with Vladykov, concluded that there was a seasonal reciprocity of landings between the southern Gulf of Maine and the Bay of Fundy. Steele suggested that the fish caught in the northern Gulf of Maine/Bay of Fundy in summer migrate south and spawn in the southern Gulf of Maine in winter. Steele did not make the same distinction as Vladykov regarding fish from the eastern and western sides of the Bay of Fundy. Steele (1963) suggested that three groups of pollock existed in the Gulf of Maine area in summer, including 1) the Bay of Fundy, 2) the group of fish found south of western Nova Scotia, and 3) the southern Gulf of Maine pollock. Steele did not comment on how distinct the three groups were.

On the basis of fishery distribution information from 1962 to 1966 (Fig. 3), Kohler (1968) suggested that there are three stocks: including 1) the Bay of Fundy and approaches, 2) Browns Bank east to the 4X/4W line and, possibly, 3) east of the 4X/4W line. The proposed stock boundaries appeared to reflect discontinuities in

the fishery distribution. It is not clear, however, why the boundary on the 4X/4W line was viewed with more uncertainty than the proposed boundary between the Bay of Fundy and the eastern portion of Div. 4X (Fig. 3).

Hare (1977) reviewed stocks of groundfish on the Scotian Shelf, and appears to have juxtaposed the views of Steele and Kohler to identify four stocks in the Gulf of Maine/Scotian Shelf, including 1) southern Gulf of Maine, 2) Georges Bank, 3) lower Bay of Fundy/southwest Nova Scotia, and 4) central Scotian Shelf (Fig. 4). Note, however, that his interpretation differs from Kohler in that Hare did not recognize a separate component at the mouth of the Bay of Fundy. Hare also showed connections between the central Scotian Shelf and the southern Gulf of Maine, but it is unclear on what these linkages were based on.

From examination of NAFO statistics that provide landings by all countries by NAFO Division (Fig. 5) from 1960 to 1998 (USA NAFO statistics are unavailable after 1998), we concluded that trends in landings data show general concurrency but there appear to be some significant differences as well. Landings in 4X were dominant among the Canadian NAFO Divisions. There was a large increase in landings in the early 1970s in 4X. This was not mirrored in the Divisions 4W and 4V. The decline in landings in 4X in the 1990s was preceded by rapid declines in adjacent Subdivisions (Subareas 5 and 6, Division 4V). Trends in landings data for Division 4W differed from other NAFO Divisions. Landings in 4W were high in the early 1960's which was a period of relatively low landings in other Divisions. The isolated peak of high landings in 4W in 1981 appears inconsistent with the fishery elsewhere. However the decreasing trend in 4W beginning in the early 1990's mirrors that in 4X. Landings in 3P have been relatively low, except for a relatively short-lived increase in 1986. Landings from Subareas 5 and 6 followed a similar increasing trend as did Div. 4X from the late 1960s to about 1985, when landings declined rapidly. This decline preceded the decline noted in Div. 4X.

Comparison of fishery distribution between two time periods (1989-1992 and 1999-2002) illustrates the impact of fishery regulations on the perceived resource distribution as indicated from fishery data. The large otter trawl fleet was a dominant component of the total fishery during 1989 to 1992, a period of relatively high total landings prior to large–scale fishery closures on the Eastern Scotian Shelf. There are two distinct fishery clusters in the earlier period: the north-east edge of the Scotian Shelf from the 4Vn/4T boundary around to the Sable Island Gully area (western boundary of 4Vsc), and the Bay of Fundy, Georges Bank and western Scotian Shelf (Fig. 6). The large mobile fleet component in the latter period (1999-2002, Fig. 7) is much reduced

compared with Fig. 6, thus areas fished by this component appear less significant. This is particularly true for the fishery concentration along the northeast edge of the Scotian Shelf identified earlier. Also the fishery is less continuous in the latter period. The fishery discontinuity off Southwest Nova, more apparent in the spring fishery, suggests a third fishery cluster around the 4W/4X boundary (Fig. 7).

Commercial fishery catch rates are used as an index of abundance in the stock assessment, and are available for Tonnage Class 1-3 vessels operating in Divs. 4WX and 5Zj. Given the observation that the spatial distribution of the fishery is patchy, and discrete fishery aggregations are noted in 4Xpq (southwest Nova Scotia), and 4Xn4Wjkl (Central Scotian Shelf) in the 1999-2002 data, we elected to show the trends in standardized catch rates for those two areas in relation to the aggregate catch rate series as used in the assessment (Fig. 8). There was also sufficient data to present a separate series for 5Zj. Although there is considerable inter-annual variation, all three areas had a period of relatively high catch rates in the 1980s, followed by declining catch rates in the 1990s. More recently, it appears as though the recent sharp increase in catch rates from 2001 to 2002 is derived largely from observations in 4Xpq. The same increase is not apparent for 5Zc or for 4Xn4Wjkl. If these areas included different populations with varying productive characteristics, divergences in catch rate series might be expected. The evidence presented here is somewhat equivocal, but in general the trends appear comparable, except for the most recent years.

The spatial distribution of the USA fishery is illustrated for gillnet and otter trawl fleets in Figs. 9 and 10, respectively. These data were compiled from vessel captain interview data from 1982 to 1990, aggregated to 10' squares. Gillnet activity occurs principally in the Gulf of Maine area, with no fishing in the deeper water near the centre. In all four quarters, the fishery distribution is contiguous up to the International Boundary near Crowell Basin. The otter trawl fleet distribution is even more wide-spread. The northern edge of Georges Bank and most of the Gulf of Maine appears to have supported the fishery on a year-round basis.

Research Vessel Surveys

In contrast to commercial fishery data, information obtained from research vessel surveys is not limited by uneven distribution of effort. The USA conducts spring (1968-present) and autumn (1963-present) surveys in the Gulf of Maine and Georges Bank area. Canada conducts annual summer (1970-present) surveys in Divs.

4V, 4W and 4X. However, during the period from 1978 to 1984, Canada enhanced its survey coverage by conducting additional surveys each spring and autumn.

Distributional information available from Canadian Scotian Shelf spring surveys conducted from 1978 to 1984 show considerable concentrations of pollock along the western edge (following the 200-m depth contour in Divs. 4X and the western portion of 4W, see highlighted area in Fig. 11) of the Scotian Shelf. Such aggregations are not evident in the summer or fall surveys. Northeast of Digby Neck in the upper Bay of Fundy, pollock are rarely caught in the spring, but are caught during the summer and fall. During all three seasons, the pollock appear generally absent in the eastern part of NAFO Div. 4W, but particularly so during the summer surveys.

To better assess the spatial contiguity of the distributions from the RV surveys, we combined data from the Scotian Shelf surveys with the adjacent areas. The southern Newfoundland spring surveys from 1985 to 1990 are juxtaposed with Scotian Shelf spring surveys from 1980-1985 in Fig. 12. The survey years selected did not match, but those years were selected since the southern Newfoundland surveys included a greater portion of the Laurentian Channel starting in 1985 and Scotian Shelf spring surveys are unavailable for that time period. While the entire width of the Laurentian Channel was not sampled, catches of pollock in the deep water of the Channel were very infrequent. We also show the trends in the age-aggregated abundance indices in the eastern Scotian Shelf (4V) to southern Newfoundland (3Ps) in Fig. 13. While the series show some concurrence in the 1980s, there was considerable digression in the remainder of the series, with the eastern Scotian Shelf data showing some high values. However, such values appear to be "year effects" often associated with unusual events such as a single large set.

The Canadian 4X surveys from 1978 to 1984 are plotted along with the USA surveys for the comparable period in the Gulf of Maine in Fig. 14 (spring surveys) and Fig. 15 (autumn surveys). During the spring surveys, catches of pollock were frequently made around the edge of Browns Bank and on the Canadian portion of Georges Bank, and in the vicinity of the International Boundary in the Gulf of Maine and throughout the Gulf of Maine. The relatively deep water of the Fundian Channel did not appear to be a natural boundary to pollock distributions, as catches were not uncommon there.

Age-disaggregated indices were available for both USA surveys and Canadian summer surveys. We compared indices of abundance from the fall USA surveys in Subarea 5 (strata 13 -29 and 36-40) to the Canadian summer surveys in Div. 4X (Fig.16). However, in both surveys neither strong nor weak year-classes were clearly identifiable due to strong "year effects" which appeared to affect both series, albeit in different years.

Finally, Canada has conducted annual spring surveys on Georges Bank since 1986. While such surveys cover only a limited portion of the stock area of pollock, they provide further insight into the spring distribution of the resource on Georges Bank, and the relative proportions of biomass on the Canadian and USA sides of the International Boundary. The distribution of catches of pollock is shown in Fig. 17. While the sampling intensity is higher on the Canadian side, the impression is that the majority of pollock catches are made to the west of the International Boundary. The relative proportion of biomass on the Canadian side of Georges Bank varies considerably, without apparent trend (Fig. 18).

Ichthyoplankton Distributions and Timing

Surveys of eggs and larvae have been conducted throughout much of the range of pollock by both Canada and the United States. Neilson and Perley (1996) documented the timing of peak spawning activity by documenting the peak numbers of early stage pollock eggs from the Scotian Shelf Ichthyoplankton Program. They found the peak number of eggs occurred in January in both the eastern (4VW) and western (4X) halves of the Scotian Shelf (Fig. 19). Hanke et al. (2001) provided the most complete information on the distribution of pollock eggs and larvae within the current management unit. When they evaluated the composite distribution of egg stages and larvae from the available ichthyoplankton surveys conducted from 1975 to 1997, discrete aggregations of early life history stages were found on Georges Bank, off southwestern Nova Scotia (NAFO Div. 4X), and in Divs. 4VW (Fig. 20). Clear spatial discontinuities existed among the aggregations described above. The continuity of eggs along the northern edge of Georges Bank in both Canadian and USA waters is also noteworthy.

Cargnelli et al. (1999) summarized available (1978-1987) USA information on ichthyoplankton distribution in the 5Y, 5Z and 4X areas, and providing insight into stock separation at the southern limit of the Canadian

management unit. The USA surveys included a north-south transect that had very closely spaced stations through the Fundian Channel (Fig. 21). While that bathymetric feature separated the aggregations apparent in the Canadian ichthyoplankton surveys described earlier, the USA surveys caught eggs at almost all the stations along the transect. Thus, the apparent division of the Georges Bank and NAFO Div. 4X aggregations described earlier may have been an artifact of the distribution of sampling.

Further to the west and closer inshore, occurrences of eggs were sometimes found in USA surveys that extended to the northeast along the New England coast, although the sampling density in that area was low compared with the rest of survey area.

Growth Rate Differences

Neilson et al. (2003) examined the increment of growth achieved by fish released in the eastern (4VW) and western (4X) halves of the current pollock management unit. They illustrated that the growth rate of pollock released in the western half of the management unit was significantly faster than those released in the east (Fig. 22). These results may reflect either genetic differences or a more favourable environment for growth. If the former explanation is valid, a more complex stock structure than the current management unit is implied.

Growth rate differences in Divs. 4W and 4X were examined in more detail for this investigation. Commercial data from 1995-2002, a period with a single age reader, were grouped to increase the sample sizes in each Unit Area. Data were grouped by season, as there was some indication of seasonal movements between 4X and 4W in the landings data. Data on age at length from the Feb. – May period suggest that 4V, 4W and 4Xmn are all quite similar, and such pollock grew slower than fish from 4Xp and 4Xq (Fig. 23). Data from June-Aug. show a similar pattern, with fish from 5Z similar to 4Xpq, and 4VW and 4Xmn all slower growing. There is no clear indication of a seasonal change in such growth rate differences. Fishing in 4Xn is primarily around LaHave Bank, and along the shelf edge. Fishing in 4Xm is primarily along the 4X/4W boundary. These two areas appear to group with adjacent areas in 4W when commercial fishery distributions are plotted (see Fig. 7, top panel).

Seasonal survey data are available for this area from the 1978-1984 period, when surveys were conducted in March, July and October. These data were also examined for possible changes among seasons. Numbers of otoliths at length were quite low for the fall survey, even when grouped among years. Summer and spring surveys, however, did have sufficient numbers. In both surveys pollock from the shelf edge in 4Xn, and the inshore areas of 4Wk showed similar growth patterns, and those from around Browns Bank were faster growing than the others (Fig. 24). This is consistent with data from the commercial fishery.

Meristics and Morphometrics

McGlade (1983) presented meristic information on pollock collected during research surveys conducted in the Scotian Shelf – Georges Bank and Gulf of Maine region. She concluded that based on a multivariate analyses, there were clear divisions among adult fish collected in the Northwest Atlantic, including: 1) the western Gulf of Maine, 2) Browns and Roseway Banks (4X), and 3) Emerald and Western Banks (4VW). McGlade and Boulding (1987) employed a morphometric approach called truss analysis to confirm the separation of adult pollock collected on the Scotian Shelf and the Western Gulf of Maine.

Genetic Investigations

There are no data for comparison of genetic variation within the current management unit. However, Mayo et al. (1989) noted that an electrophoretic analysis of 28 enzyme systems in pollock tissue from Emerald Basin (Scotian Shelf) and Jeffreys Ledge (Western Gulf of Maine) revealed no significant differences. Cargnelli et al. (1999) suggest that the genetic differentiation of pollock off eastern North America could be better resolved using more advanced genetic (e.g. microsatellite DNA markers) and biochemical techniques (e.g. elemental fingerprinting of otoliths).

Mark-Recapture Studies – Release and Recaptures Within the Management Unit

Over the period 1978 to 1984, an extensive tagging program of pollock was conducted in the Canadian Maritimes and off southwest Newfoundland (Clay et al. 1989). The tagging was done using dart tags with nylon T anchors (Floy Manufacturing, Seattle, Washington, USA). The tags were inserted in the dorso-lateral region,

posterior to the first dorsal fin. Releases totaled 55,865 pollock. The fish marked and released were typically ages 2 and younger (Neilson et al., 2003). The sites of release and numbers of releases by year are provided in Fig. 25. Almost all the fish that were marked and released were caught in inshore traps or by handlining. This approach yielded fish that were in good condition. Previous attempts to capture larger fish in bottom trawl operations were unsuccessful, as the fish captured in trawls were moribund even after short (10 min) duration sets.

Recaptures totaled 5,615 individuals (about 10% of the total releases). Neilson et al. (submitted) examined these data, and included only those fish that had been at liberty for more than 30 days, and where Unit Area of recapture was known. This reduced the number of fish available for the analysis to 3,784. To evaluate if the mark-recapture information provided in this paper supports the inference of stock discreteness within the current management unit, Neilson et al. (submitted) divided the recapture information into eastern (N=1594) and western (N=2190) components using the conventions followed in Neilson et al. (2003) who considered the eastern Scotian Shelf to include NAFO Divs. 4VW and the western Scotian Shelf to include Div. 4X.

When interpreting the results of mark-recapture studies, it is desirable to have an appreciation of the distribution of recapture effort. Since pollock is caught as a bycatch to other groundfish fisheries as well as in directed fisheries, Neilson et al. (submitted) described the spatial distribution of all groundfish fishing effort. Detailed catch and effort data were available for mobile gear during the period of tag recaptures. The catch and effort data collected by the Canadian Department of Fisheries and Oceans provide species composition, date of landing, statistical area (which includes either Northwest Atlantic Fisheries Organization (NAFO) Statistical Divisions or at a finer geographic scale, Departmental statistical divisions referred to as Unit Areas (Fig. 1)), gear and mesh type, and tonnage class, among other information. The data are grouped into 'subtrips', which denote a period of fishing activity in a given 24 h period, or within a given Unit Area, or with a particular gear type. If any of the three conditions change, then a new subtrip is considered to have started.

Standardized groundfish effort for the period when tags were returned was investigated using a multiplicative model (Gavaris 1980). This approach examines relationships between groundfish catch rate and factors such as statistical area, tonnage class, month, trawler type (stern and side trawler), and groundfish

species targeted (cod, haddock or pollock). We considered these factors as main effects only, and possible interactions were not explored. Each level of a factor required a separate regressor to be estimated. These estimates were used to provide estimates of standardized mobile gear effort for each Unit Area over the period when tags were returned. Although pollock are also caught in fixed gear such as gillnets and handlines, there were insufficient data to allow catch rate standardization during the period of tag returns.

The distribution of standardized mobile gear fishing effort is shown graphically by Unit Area on Fig. 26. Areas of particular concentration of mobile gear effort associated with the pollock fishery included Unit Areas 4Vsc, 4Vn, 4Xn, and 5Zj. Using the distribution of standardized mobile gear effort among all Unit Areas comprising the management unit and assuming that tagged fish moved freely throughout the management unit, Neilson et al. (submitted) then predicted the distribution of recaptured fish by the mobile gear fishery and compared them with the observed distribution (Fig. 27).

Of the 1139 recaptures made by mobile gear from eastern releases, 73% (832) were made in the eastern half of the management unit. While all releases were made from coastal locations, the larger recaptures were made in offshore Unit Areas such as 4Vsc and 4Wh. There was a trend of fewer recaptures than expected in the western Unit Areas further from the eastern release sites. The observed number of recaptures was close to the expected number of recaptures in only a few instances (4Vsc, 4We and 4Xn). Of the pollock that crossed from the eastern to the western half of the management unit, only those recaptured in 4Xn occurred in numbers close to expectations, given the distribution of fishing effort (99 expected, and 140 observed). Two Unit Areas (4Wh and 4Wk) had considerably higher recaptures than expected. The two Unit Areas (4Vn, 4Vsb) near the northern limit of the management unit had lower occurrences of recaptures than expected given the distribution of fishing effort.

Of the 504 recaptures made by mobile gear from western releases, 93% of recaptured fish were caught within the western half of the management unit. The largest number of recaptures was associated with 4Xq and greatly exceeded the expected number of recaptures (45 expected, 170 observed).

In general, the spatial distribution of recaptured fish in the fixed gear fishery also did not indicate a tendency to mix freely throughout the management unit (Fig. 28). Area 4Wd, however, was associated with a

considerably higher (73%) proportion of recaptures in the fixed gear fishery compared with the mobile gear fishery (2%). Area 4Wd also had the greatest number (479) of recaptures of eastern-released fish of all Unit Areas. Of the pollock released on the eastern side of the management unit, 83% were recaptured there.

From the western releases recaptured in the fixed gear fishery, the largest number of recaptures was noted in 4Xo (1,053, Fig. 28). Of the pollock released on the western side of the management unit, over 99% were recaptured there, with only four recaptures coming from the eastern half of the management unit.

Mark-Recapture -- Movement to Areas Outside the Management Unit

Of the fish that moved outside the management unit, 36 recaptures were reported from waters around Newfoundland (includes NAFO Areas 2 and 3), 7 were recaptured in the northern Gulf of St. Lawrence, and 88 were recaptured in USA waters. Of the 36 recoveries in Newfoundland waters, 32 were from the nearest point of release adjacent to the northern limit of the management unit (4Wd, Fig. 29). All the recaptures in the Gulf of St. Lawrence also originated from that point of release. Of the recaptures in waters around Newfoundland, 20 of the 36 were reported as being caught off northern Newfoundland or Labrador. Given that the tonnage of pollock landed in this area was extremely small during the period of recaptures, we consider that these reports to be of uncertain validity, and consequently the returns from northern Newfoundland and Labrador are not shown in Fig. 29.

Releases from five sites crossed into USA waters, with 64 originating from the western Bay of Fundy, 10 from the eastern Bay of Fundy, 5 from southwest Nova Scotia, 1 from Halifax area, and 8 from the Canso area. Some of the longest distances between release and recapture were noted for the latter recaptures, with movements of over 400 nautical miles noted for individual fish.

The difference in the number of recaptures moving into USA waters from the releases from the eastern and western sides of the Bay of Fundy is noteworthy (Fig. 30). From the releases of pollock on the western side of the Bay of Fundy (N = 15,834), there were 412 recaptures, of which 64 were taken in USA waters (15.5% of

all recaptures). From the eastern side, there were 6,081 releases and 258 recaptures, of which 10 were captured in USA waters (3.8% of all recaptures).

Concerning movements from fish marked and released outside the current management unit, of 312 fish released off southern-western Newfoundland, 33 were recaptured and recapture coordinates were reported in 16 cases (Fig. 31). Fifteen were recaptured off southern Newfoundland, 8 were recaptured in the Gulf of St. Lawrence, and the remaining 10 were recaptured on the Scotian Shelf. No mark-recapture experiments involving pollock have been undertaken in USA waters, so it is not possible to comment on the potential immigration across the southern boundary of the management unit.

Conclusions and Recommendations

Table 1 summarizes the information presented in this document. The main options regarding the management unit structure are given, along with available data of different types that inform decisions about stock structure.

The *status quo* option of a single management unit for 4VWX5Zc is not consistent with the available information on population complexity. Of all data types available, only the information on timing of spawning supports the hypothesis of a single stock, since there is no difference in timing of reproduction on the eastern and western Scotian Shelf. All other data point to the need for creation of smaller management units to better protect populations which likely differ in their productive capacity and to preserve the diversity of the pollock stocks.

Starting from the east, we suggest that creation of an eastern Scotian Shelf management unit (4VW) is generally supported by the available data. Egg and larval surveys show a discontinuity close to the 4X/4W line. Growth rate differences and meristic/morphometric differences have been noted between the eastern and western components. The tagging data support this conclusion as well, as only limited movement is noted from Div. 4X releases into 4W and vice-versa. Considering growth rate differences on a finer scale, 4Xn and the edge strata in 4X surveys appear to be associated with slower growth more typical of pollock in 4VW. Such differences could be recognized in the construction of the catch at age and in abundance indices.

Should the recommendation of a 4VW/4X split be accepted, managers should give special note to the slower growing component that straddles the boundary. While landings from 4Xmn and 4Wkl are currently very low, these unit areas have supported substantial fisheries in the past (Table 2). The inclusion of the slower growing component warrants caution and continued monitoring of the fishery landings by unit area.

Concerning the boundary of the 4VW management unit with the Gulf of St. Lawrence, pollock do not occur frequently in the Gulf of St. Lawrence, and the tagging information shows few returns from that area. Given these observations, we consider it appropriate to retain the northwestern boundary of this stock at the line between 4Vn and 4T (southern Gulf of St. Lawrence).

Considering the northeastern boundary with 3Ps, conclusions are somewhat less clear with the data available. The latest Stock Status Report (DFO, A2-07 2002) indicates that pollock are not incidental visitors to the waters of southern Newfoundland. Pollock are reported in the catch statistics in every month, and occur as juveniles in coastal waters in 3Ps. Pollock are also caught at various stages of maturity during surveys. The SSR concluded that pollock are probably spawning in 3Ps, but no ichthyoplankton survey data were available to confirm this observation. On the other hand, the tagging information indicated considerable exchange with fish on the eastern Scotian Shelf, and fishery distributions indicated that pollock were caught in the Laurentian Channel, further confirming that this deep-water channel is not a constraint to pollock movement. However, current population assessments consider the abundance of ages 3+ typically, and immigration/emigration of younger ages would not be detected or influence management decisions at present. Given these considerations, it is probably appropriate to retain the current north-east boundary with Div. 3Ps.

With regard to the western management unit, the current boundary in 5Zj is not supported by the ichthyoplankton data that show a transboundary distribution of eggs along the northern half of Georges Bank. However, the MARMAP data show some continuity with ichthyoplankton distributions in 4X. Fish from 5Zc show growth rates that are more comparable to 4Xpq than fish further to the east. Thus, it is probably appropriate to group 5Zc with Div. 4X. The most appropriate placement of the boundary on Georges Bank is more problematic, however. The USA fishery distribution information from 1982 to 1990 (otter trawl) indicated no discontinuities in the vicinity of the International Boundary. On the other hand, survey distributions appear to

indicate that the International Boundary approximates discontinuities in the distribution of pollock. This is particularly true for the spring surveys (Fig. 14). In the absence of further information to guide this decision, we suggest it is appropriate to retain the International Boundary as the southern stock limit. Such a view is largely based on pragmatic considerations however, and further research could allow better definition of the stock boundary. As the recent USA landings are now close to the Canadian landings in magnitude, the implications of an inappropriate decision are becoming more serious.

In our view, the historic literature that postulates a seasonal movement of pollock along the New England coast is likely correct, and has some analogies with studies of cod and haddock stocks in the area (see, for example Clark and Vladykov 1960). However, the Canadian landings of pollock in Unit Area 4Xs (western Bay of Fundy) have typically been small (Table 2). Rather than creating a potential management problem by declaring such removals "non-stock", we consider it appropriate to group these landings with removals in the rest of the proposed 4X5Zc management unit.

Acknowledgments

We thank Eugene Murphy, Department of Fisheries and Oceans, Newfoundland Region for provision of the 3Ps survey data. Ralph Mayo, National Marine Fisheries Service, Woods Hole Laboratory, kindly provided the figures showing the distribution of the USA fishery. Alex Hanke provided Figure 1b. We thank David Packer, USA NMFS, for permission to reproduce the figure appearing in this document as Figure 12. R. Halliday, as part of an internal review of the submitted manuscript, provided helpful comments on the mark-recapture portion of this contribution. This document was improved by suggestions from K. Clark.

Literature Cited

Anon. 1973. International Commission for the northwest Atlantic Fisheries Annual Proceedings. 23: 83,90.

Bowen, W.D. 1987. A review of stock structure in the Gulf of Maine Area: a workshop report. CAFSAC Research Document 87/21, 51 p.

Booke, H.E. 1981. The conundrum of the stock concept – are nature and nurture definable in fishery science? Can. J. Fish. Aquat. Sci. 38: 1479-1480.

Cargnelli, L.M., Griesbach, S.J., Packer, D.B., Berrien, P.L., Johnson, D.L., and W.W. Morse. 1999. Pollock, *Pollachius virens*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-131, 30 p.

Clark, J.R. and V.D. Vladykov. 1960. Definition of haddock stocks of the Northwestern Atlantic. Fish. Bull. 60: 283-296.

Clark, S.H., Burns, T.S., and R.G. Halliday. 1976. A preliminary assessment of the pollock fishery in ICNAF Divisions 4VWX and Subarea 5. ICNAF Res. Doc., No. 47, Serial No. 3833, 27 p.

Clay, D., Stobo, W.T., Beck, B., and P.C.F. Hurley. 1989. Growth of juvenile pollock (*Pollachius virens* L.) along the Atlantic coast of Canada with inferences of inshore-offshore movements. J. Northwest Atl. Fish. Sci. 9: 37-43.

DFO, 2002. Subdivision 3Ps pollock. DFO Science Stock Status Report A2-07(2002).

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Gulland, J.A. 1983. Fish Stock Assessment. FAO/Wiley Series on Food and Agriculture. John Wiley and Sons, Chichester, 223 p.

Hanke, A.R., Page, F.H. and J. Neilson. 2001. Distribution of pollock (*Pollachius virens)* eggs and larvae on the Scotian Shelf, Eastern Gulf of Maine, Bay of Fundy and Eastern Scotian Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2345, 120 p.

Hare, G.M. 1977. Atlas of the major Atlantic coast fish and invertebrate resources adjacent to the Canada-United State boundary areas. Fish. Mar. Serv. Res. Dev. Tech. Rep. 681, 97 p.

Kohler, A.C. 1968. Fish stocks of the Nova Scotia banks and Gulf of St. Lawrence. Fish. Res. Board Can. Tech. Rep. 80, 25 p.

McGlade, J.M., 1983. Preliminary study of of the stock structure of pollock (*Pollachius virens* L.). Canadian Atlantic Fisheries Scientific Advisory Committee 83/81, 21 p.

McGlade, J.M., and Boulding, E.G. 1987. The truss: a geometric and statistical approach to the analysis of form in fishes. Can. Tech. Rep of Fish. Aquat. Sci. 1457, 34 p.

Mayo, R. K., McGlade, J.M., and Clark, S. 1989. Patterns of exploitation and biological status of pollock (*Pollachius virens* L.) in the Scotian Shelf, Georges Bank, and Gulf of Maine Area. J. Northwest Atl. Fish. Sci. 9: 13-36.

Neilson, J.D. and P. Perley. 1996. Can ichthyoplankton data be used to describe spawning areas of marine fish? In: (D.L. Burke, R.N. O'Boyle, P. Partington and M. Sinclair, eds.) Report of the Second Workshop on Scotia-Fundy Groundfish Management. Can. Tech. Rep of Fish. Aquat. Sci. 2100: 129-146.

Neilson, J.D, Stobo, W.T., and Perley, P. 2003. Age and growth of Canadian East Coast pollock: comparison of results from otolith examination and mark-recapture studies. Trans. Amer. Fish. Soc. 132: 536-545.

Neilson, J.D, Stobo, W.T., and Perley, P. Submitted. Pollock (*Pollachius virens* (L.)) Stock Structure in the Northwest Atlantic Inferred from Mark-recapture Studies. ICES J. Mar. Sci.

Steele, D.H. 1963. Pollock, (*Pollachius virens* (L.)) in the Bay of Fundy. J. Fish Res. Bd. Can. 20:1267-1314.

Stephenson, R.L. 1999. Stock complexity in fisheries management: a perspective of emerging issues related to population sub-units. Fish. Res. 43: 247-249.

Vladykov, V.D. 1932. The pollock fishery of the Fundy area. Unpublished MS in Library, Biological Station, St. Andrews, N.B., 116

Table 1. Summary of management unit decision options and supporting data.

				Management Unit Decision Options			
Type of Data	*Retain Status Quo (4VWX5Zc)*	*Split into western/eastern (4X5Zc/4**VW**)*	*Split into western/eastern (4X**opqrs**5Zc/ 4**VWXnm**)*	*Add Central Scotian Shelf Component (4Xmn4Wjkl), distinct from 4V and 4X (western)*	*Add Transboundary Georges Bank Separate from 4X or 4WX*	*Add Transboundary Western GOM Component Separate from 4X or 4WX*	*Consider 3Ps Separate from 4V or 4VW (status quo)*
Fishery	H Fishery distn shows discontinuities	H	H	Γ	Γ Fish not common in Fundian Channel	Γ Based on historical fishing patterns	H Some pollock caught in Laurentian Channel
RV Surveys	HDiscontinuities present in survey distributions	H Pollock distribution discontinuity is further east	H Pollock distribution discontinuity is further east	H Only one discontinuity noted in central Shelf	Γ Fish not common in Fundian Channel, but pollock catches infrequent in surveys	Γ Seasonal CDN surveys suggest pollock more abundant in west BOF in summer	Γ Pollock catches in Laurentian Channel were rare – mostly along edges on both sides.
Egg and Larval Surveys	ΓLack of difference in spawning timing consistent with single stock	Γ Egg distributions show discontinuity around 4X/4W line	H Egg distribution discontinuity is further east	H Only one discontinuity noted in central Shelf	Γ? Equivocal evidence of discontinuous distributions from 5Z to 4X – sampling artifact?	Γ MARMAP data show continuity of egg distns along New England Coast	n/a, but fish in reproductive state found in 3Ps surveys, and juveniles found in coastal Nfld waters
Growth Rates	H	Γ Western fish faster growing	Γ Best reflects differences in growth rates		H Growth rates in 5Zc similar to 4Xpq	n/a	n/a
Meristics and Morphometrics	H	Γ	n/a	n/a	n/a	n/a	n/a
Genetic Investigations	n/a Comparison of enzyme systems between Scotian Shelf and Western GOM revealed no differences	n/a	n/a	n/a	n/a	n/a	n/a
Mark Recapture	H	Γ Western releases rarely move to east, somewhat more frequent opposite direction			n/a	Γ Releases from West BOF show some affinity with US GOM area	H Significant mixing from 4V to 3Ps and vice-versa

Table 2. Canadian pollock landings by unit area, 1972 –2002.

YEAR	4VNn	4VNu	4VSb	4VSc	4VSe	4VSs	4VSu	4Vu	4W f	4Wd	4We	4Wf	4Wg	4Wh	4Wj	4Wk	4Wl	4Wm	4Wu	4Xl	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Yb	5ZEj	5ZEm
1972	14		2	184		13		32		3	34	14	17	50	40	1	14		937		865	1521	2179	2159	6126	1658	471		147	1080	1
1973	136		0	23		21				75	6		0	9	7	1339	101		1683		1262	3281	3803	667	8053	3259	1271	118	261	1406	1
1974	55		3	60		22				189	14	2		169	0	554	267		1474		2657	2764	3550	1613	4098	3053	851	16	679	2854	0
1975	103		1	568		29															1143	2813	2733	960	2493	1419	120	6045	407	4312	16
1976	45		0	178		63				46	2		18	234	1	663	110		1087		3032	2198	7108	681	2530	3245	191	14	48	2045	9
1977	164		28	1110		11				40	134	6	17	1701	679	1127	1790		267		1001	2315	2198	1282	980	1308	124	4924	234	3077	45
1978	54		10	2536				77		269	116	9	39	717	1620	609	823		158		3364	3187	2460	2518	1698	1158	187	377	339	4019	189
1979	283		274	3837				264		73	230	34	115	666	24	1886	827		69		3524	3273	3618	1245	3276	1857	644	423	570	1967	144
1980	393		184	2913				79		10	239	34	153	2142	527	2313	778	0	250		4488	3925	3791	895	2308	2499	1854	145	530	4416	172
1981	169		105	1812	1			44		122	141	78	83	2307	5503	2186	2395	45	1848		4051	4173	3283	2290	1598	1822	1083	308	700	3081	137
1982	149		127	2088	1			162		4	89	8	230	904	3181	1987	2469	25	69		4341	3154	4781	1499	2675	2508	1345	213	895	4198	69
1983	104		614	4601				13		7	189	24	621	1577	235	1725	702	7	191	10	2713	2532	4337	1146	3635	1170	461	1568	943	3035	59
1984	351		192	4407				101		5	60	9	207	1699	252	2061	1406		106	4	2251	3805	3536	1189	4541	716	163	2651	1724	940	15
1985	839		604	8771				7		79	80	6	1002	198	32	1156	247		43		4803	3014	6179	595	5718	1284	696	4378	757	619	2
1986	1379		1574	10065				138		202	30	2	658	289	454	986	239		220	2	4124	2448	7326	1073	2531	1046	1287	3007	613	945	2
1987	915		2046	7634				303		70	26	0	416	92	659	2302	29		154		4947	5987	4734	2329	1893	508	1209	4000	1021	1461	29
1988	1448		1636	7671				224		128	85	10	746	124	44	934	841		165		5020	2599	3194	3417	3333	307	790	5457	327	1135	16
1989	4465		1202	6062	2		276		30	253	79		313	253	272	1394	931	6	309		4239	5689	3619	3373	2334	332	374	3144	518	1110	6
1990	2124		733	5252			80		80	90	20		769	160	300	1172	1093	46	350	7	3078	3886	3668	2523	2953	1042	693	4142	345	1261	10
1991	1043		384	2599			26		7	193	42		2146	132	477	1329	2229	106	72		2824	5172	4621	3745	2665	2465	2105	1408	456	1394	20
1992	284		258	1870			1		13	149	98		990	101	162	1064	2695	44	387		1594	5357	4174	1528	2626	2175	1793	1167	443	2902	92
1993	86		51	692	0		0		1	81	470		114	6	5	588	272	1	63	13	739	2563	2754	1985	2226	1605	982	409	368	4088	44
1994	437		42	279			8		0	19	434	0	69	11	4	787	60		6		878	1128	1860	1097	1213	1453	866	1074	232	2769	16
1995	397		32	573	0		61			36	3	0	108	31	1	130	188	6	135		220	592	429	1158	2552	676	393	808	250	942	33
1996	30		30	391			11			35	0	0	19	44	0	747	67	1	81		305	898	419	1478	1811	686	412	215	256	1158	7
1997	6	5	1	43			90			7	1	0	1	94	0	606	66	1	73	15	305	770	446	1574	4030	1112	607	527	308	1072	24
1998	155		0	137			34			11	16	0	36	63	2	149	1160	1	20	0	257	1767	437	3495	3134	564	469	177	424	1605	25
1999		29	1	411			11			0	0		80	61	1	1067	248	0	3	0	247	803	313	879	1372	648	380	47	135	888	11
2000		6	0	234						0	0		20	2	0	145	85	0	7		153	239	257	1086	1531	264	249	52	136	1099	65
2001		0	0	91			3			0	0		7	2	0	128	151	2	15		146	336	207	1191	1774	301	186	74	104	1514	18
2002		0	0	39							0		0	2	0	37	39	0	1		76	317	199	1480	2628	188	159	49	157	1529	15

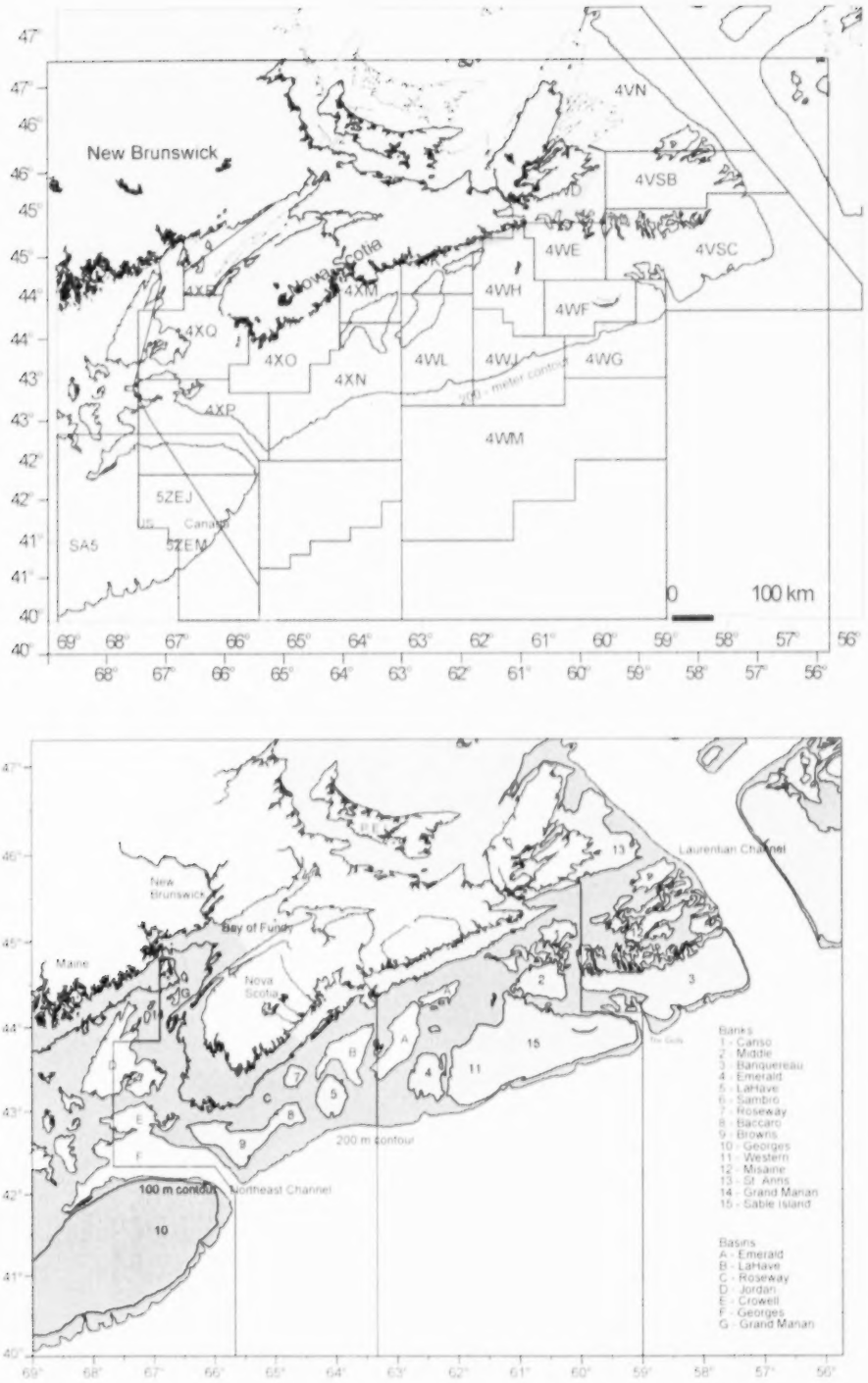


Fig. 1 The Scotian Shelf, showing the boundaries for the statistical Unit Areas. The management unit for pollock in Canadian Maritime waters includes North Atlantic Fisheries Organization Divisions 5Zc, and 4VWX. The USA/Canada international boundary on the western side of the management unit and the 200-m depth contour are shown. The bottom panel shows the bathymetric features referred to in the text.

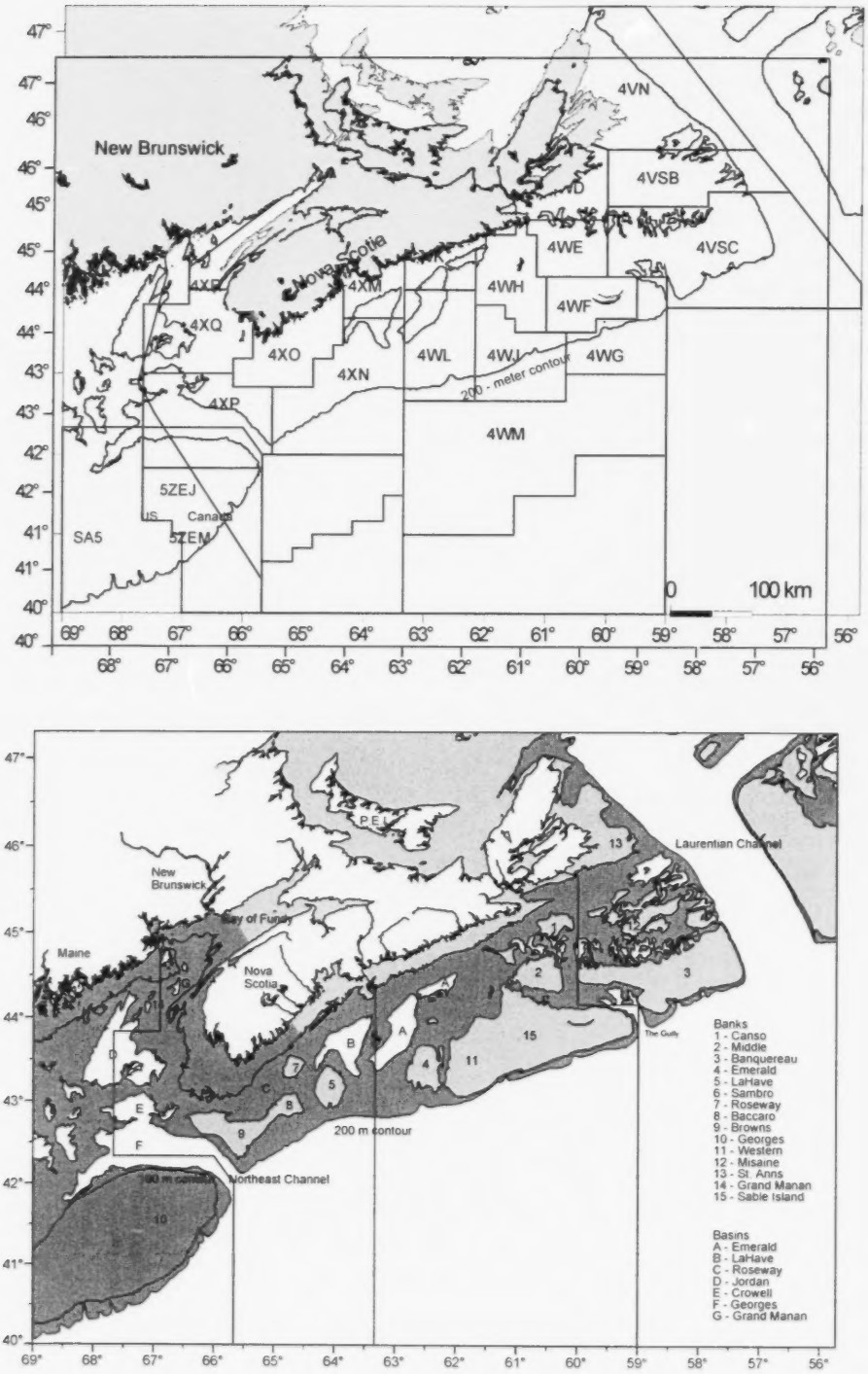


Fig. 1. The Scotian Shelf, showing the boundaries for the statistical Unit Areas. The management unit for pollock in Canadian Maritime waters includes North Atlantic Fisheries Organization Divisions 5Zc, and 4VWX. The USA/Canada international boundary on the western side of the management unit and the 200-m depth contour are shown. The bottom panel shows the bathymetric features referred to in the text.

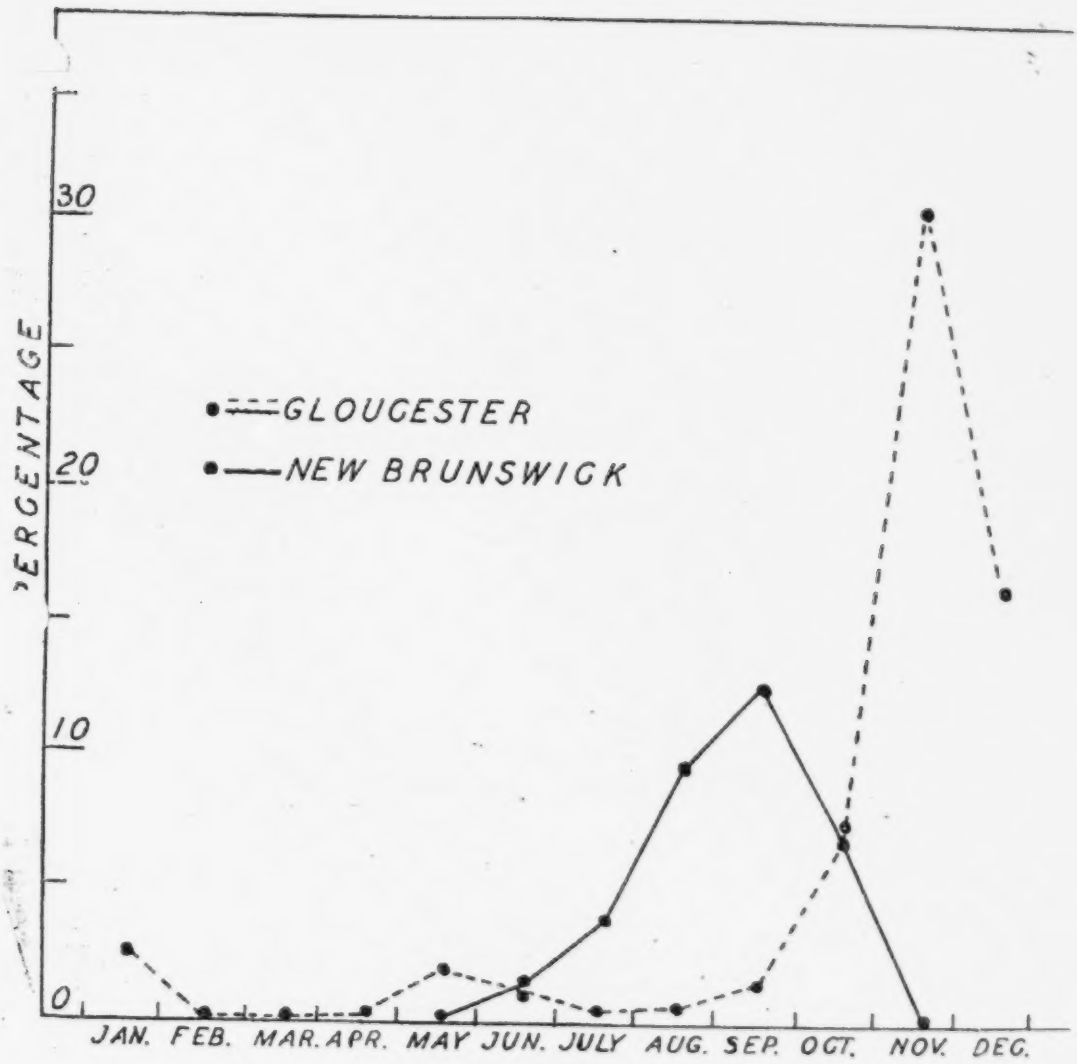


Fig. 2. Average monthly pollock catch (1926-1929) expressed as a percentage of the yearly catch, considered separately for New Brunswick and Gloucester, MA (from an unpublished manuscript of Vladykov 1932).

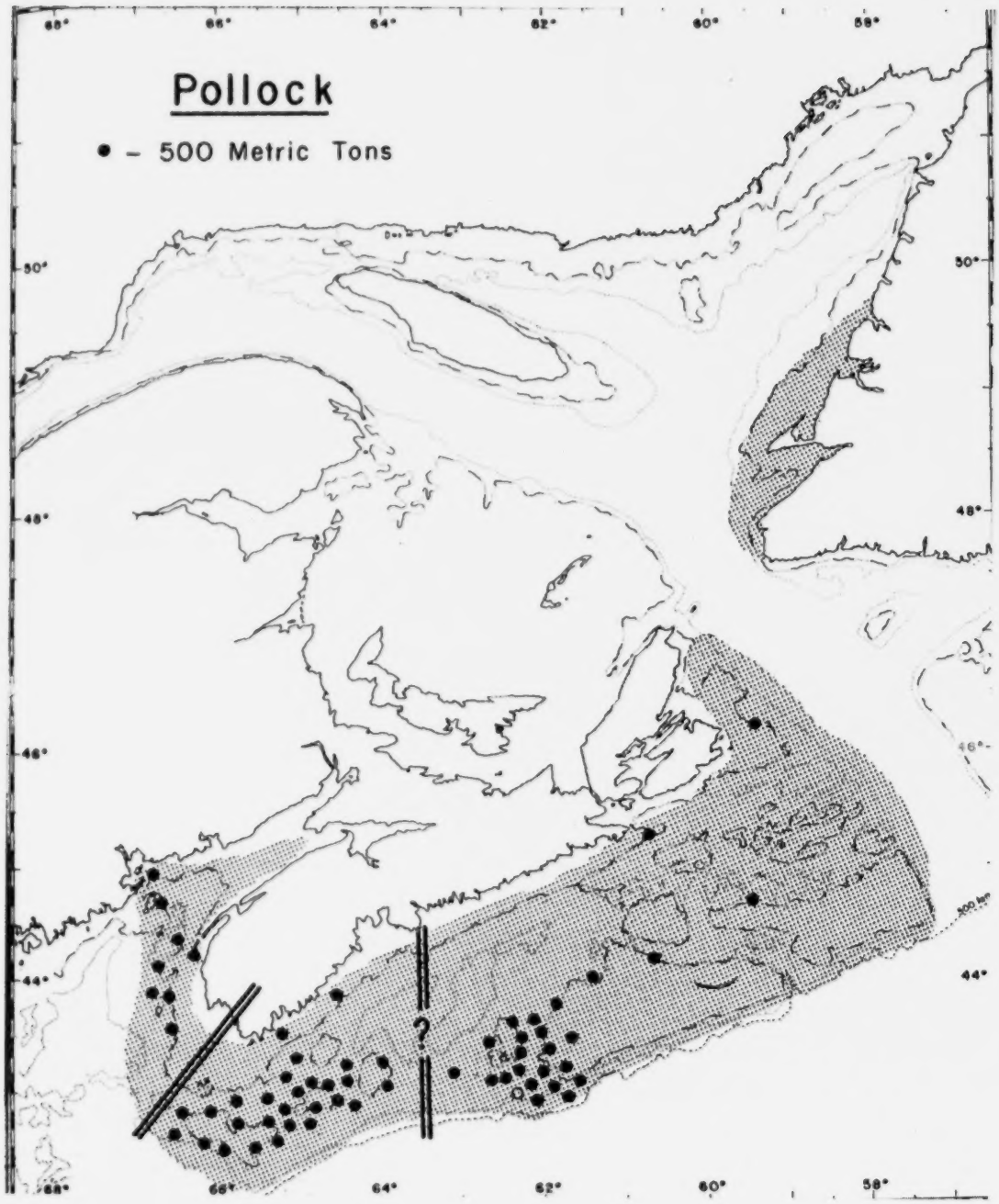


Fig. 3. Distribution of pollock from 1962 to 1966 in Canadian fisheries (Kohler 1968). Lines represent an interpretation of stock structure provided by that author, based on discontinuities in the distribution of the fishery.

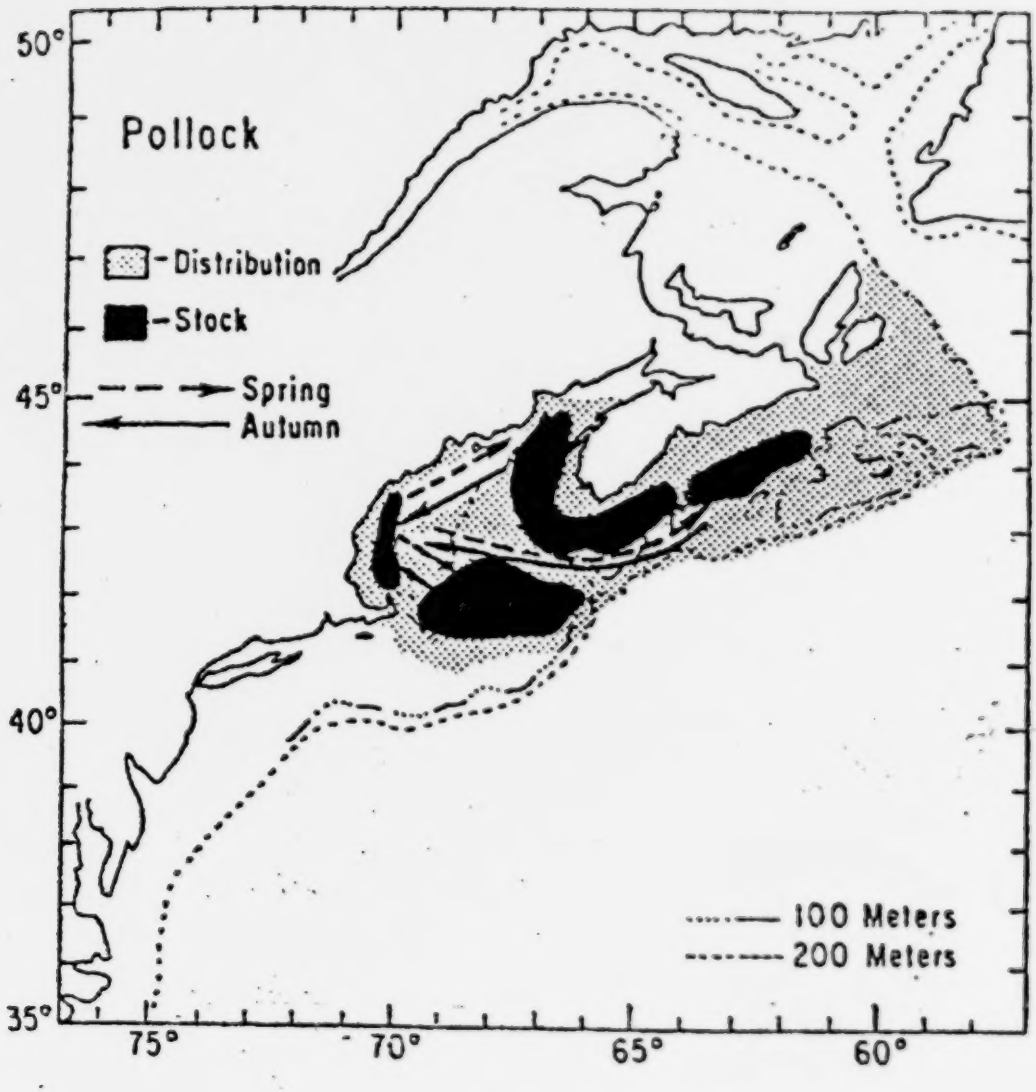


Fig. 4. View of pollock stock structure in the Gulf of Maine/Scotian Shelf provided by Hare (1977).

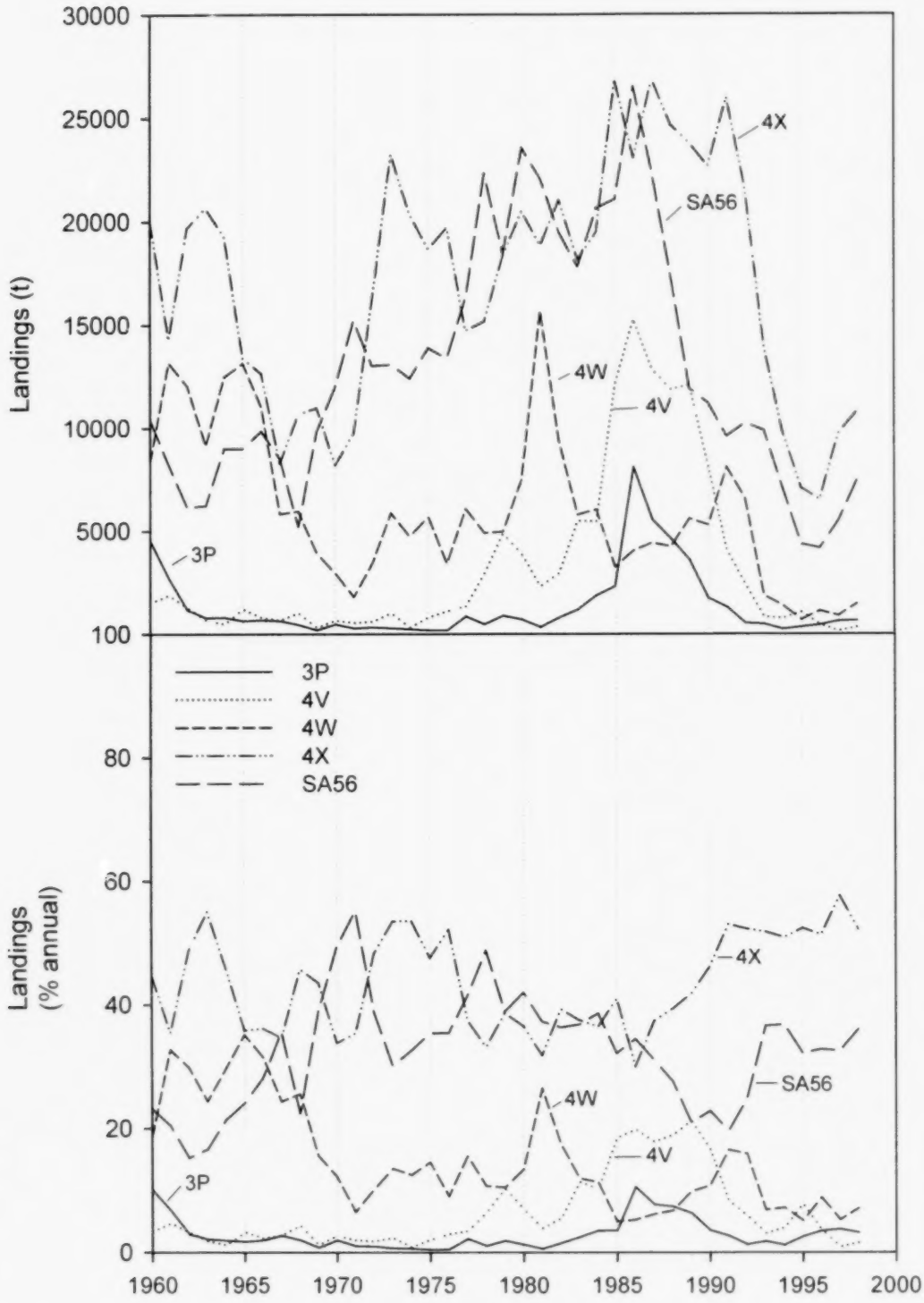


Fig. 5. Distribution of pollock landings by NAFO Subdivision, 1960-1998. The top panel shows landings as tonnage and the bottom panel shows the data expressed as percentages of annual catch.

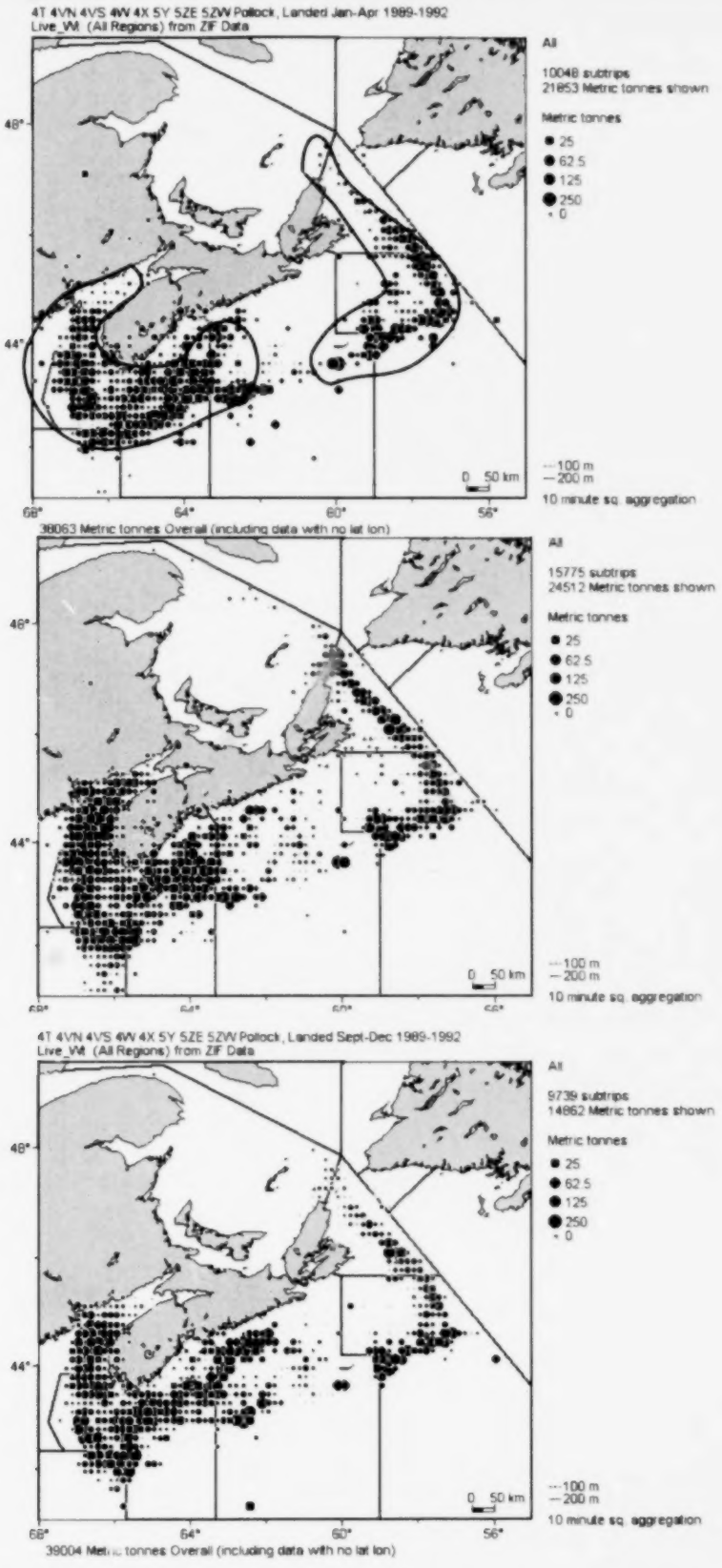


Fig. 6. Distribution of pollock landings by all gear types, 1989-1992, by trimester. Clusters of fishery activity in this period are circled.

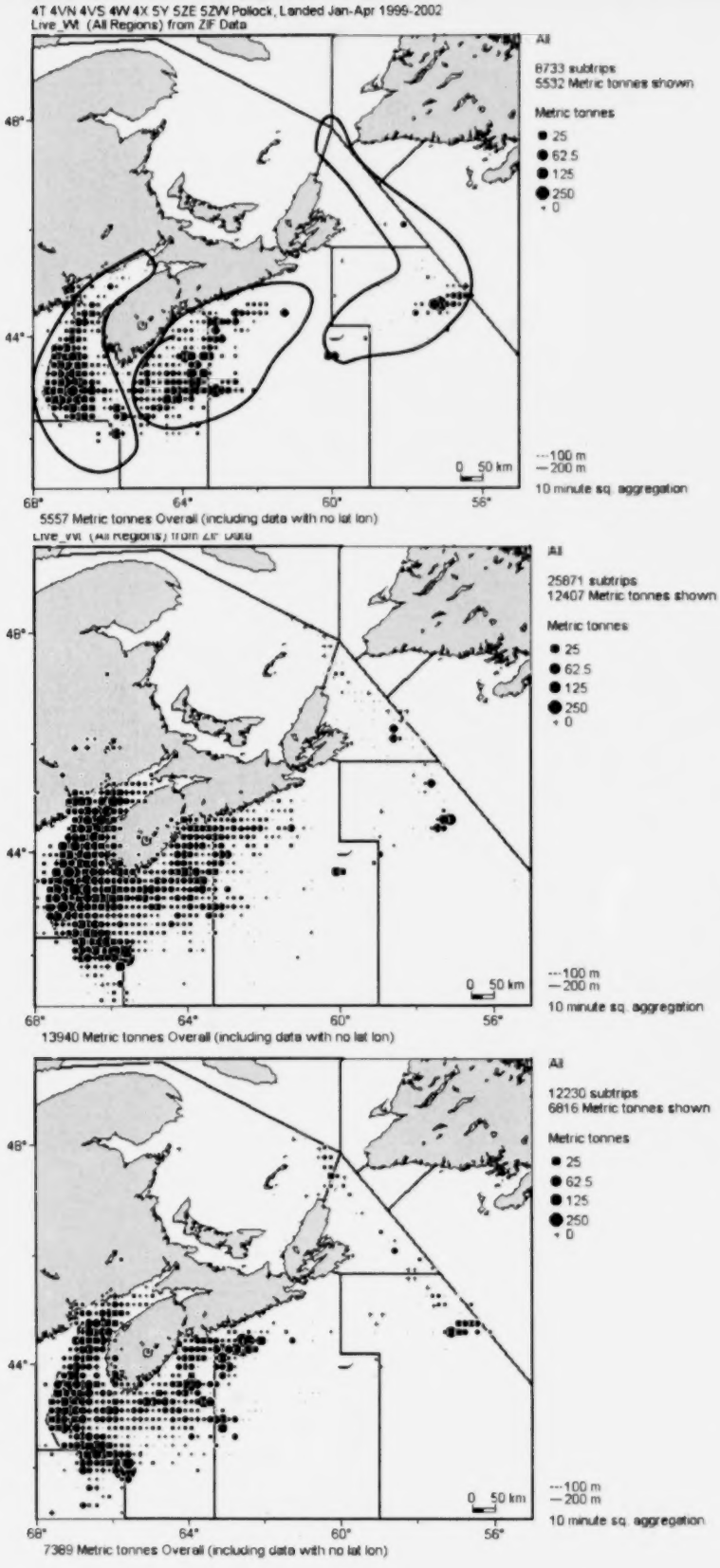


Fig. 7. Distribution of pollock landings by all gear types, 1999-2002, by trimester. Clusters of fishing activity for this period and 1989-1992 are circled.

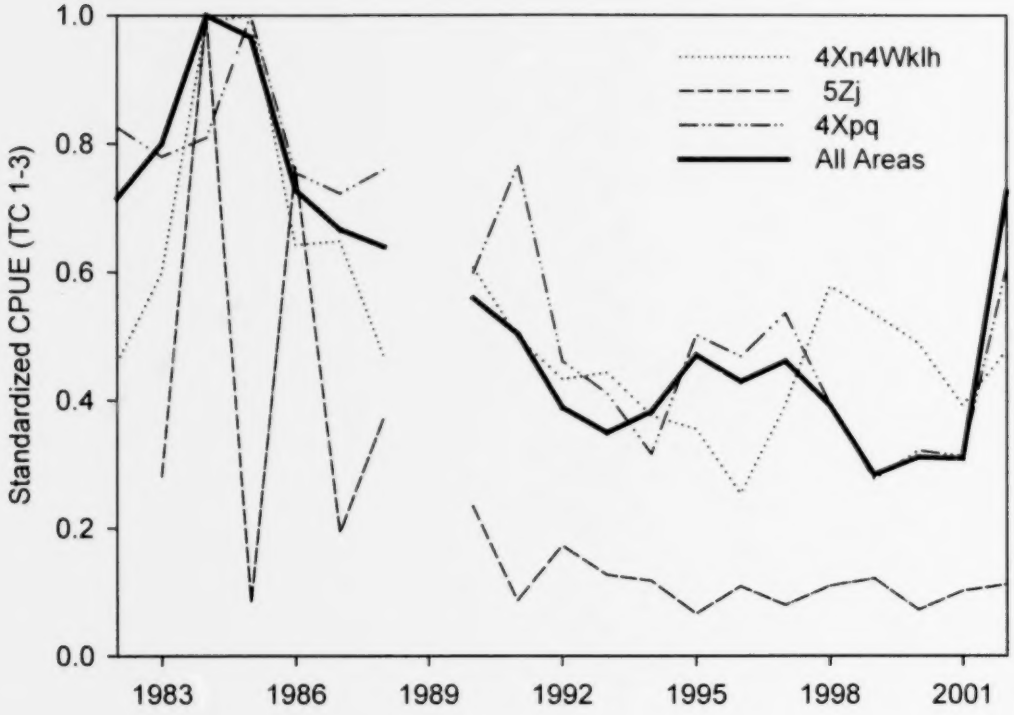
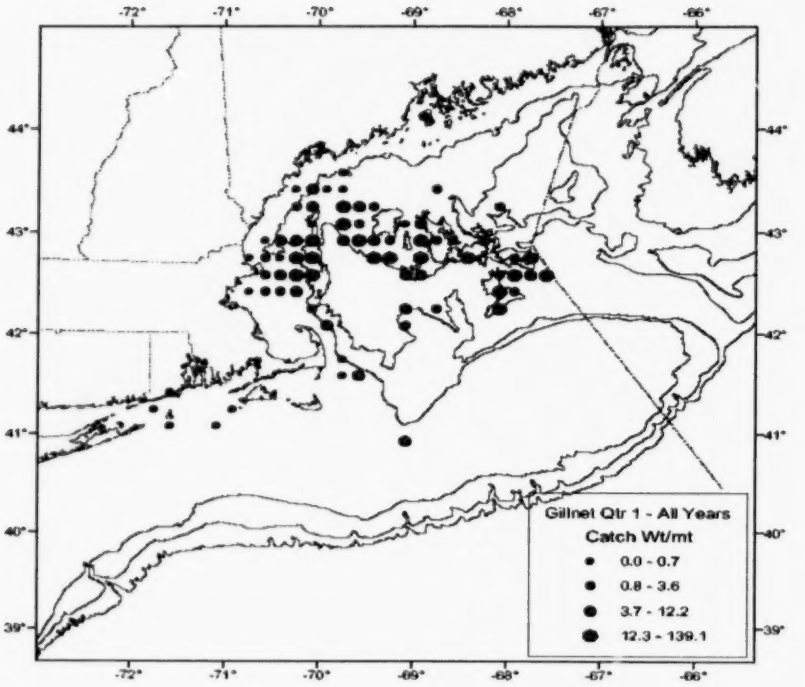


Fig. 8. Standardized CPUE series for Tonnage Class 1-3 vessels, operating on Georges Bank (5Zj), south-western Nova Scotia (4Xpq), and the central Scotian Shelf (4Xn4Wklh).



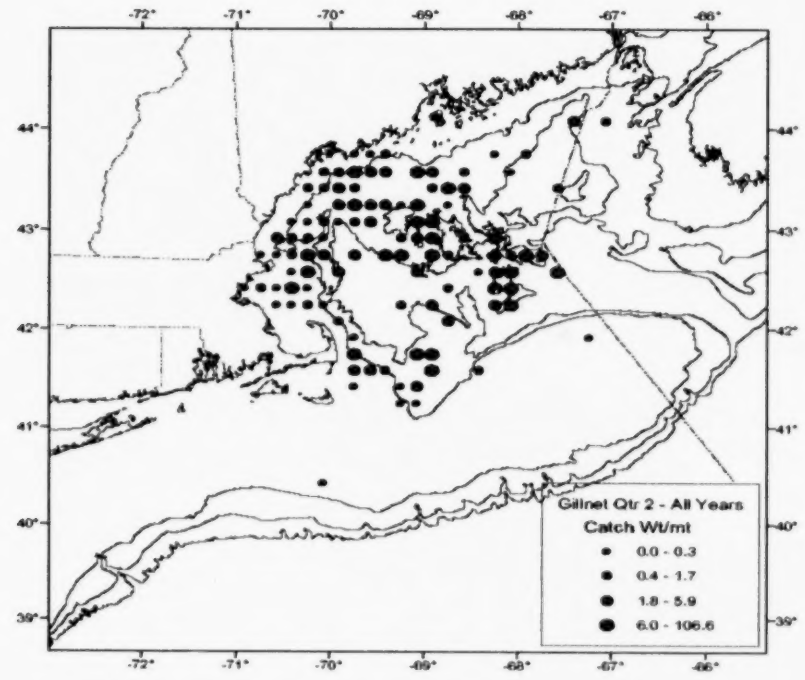


Fig. 9. Distribution of landings by the USA gillnet fleet 1982 to 1990, based on interview data aggregated on 10' squares.

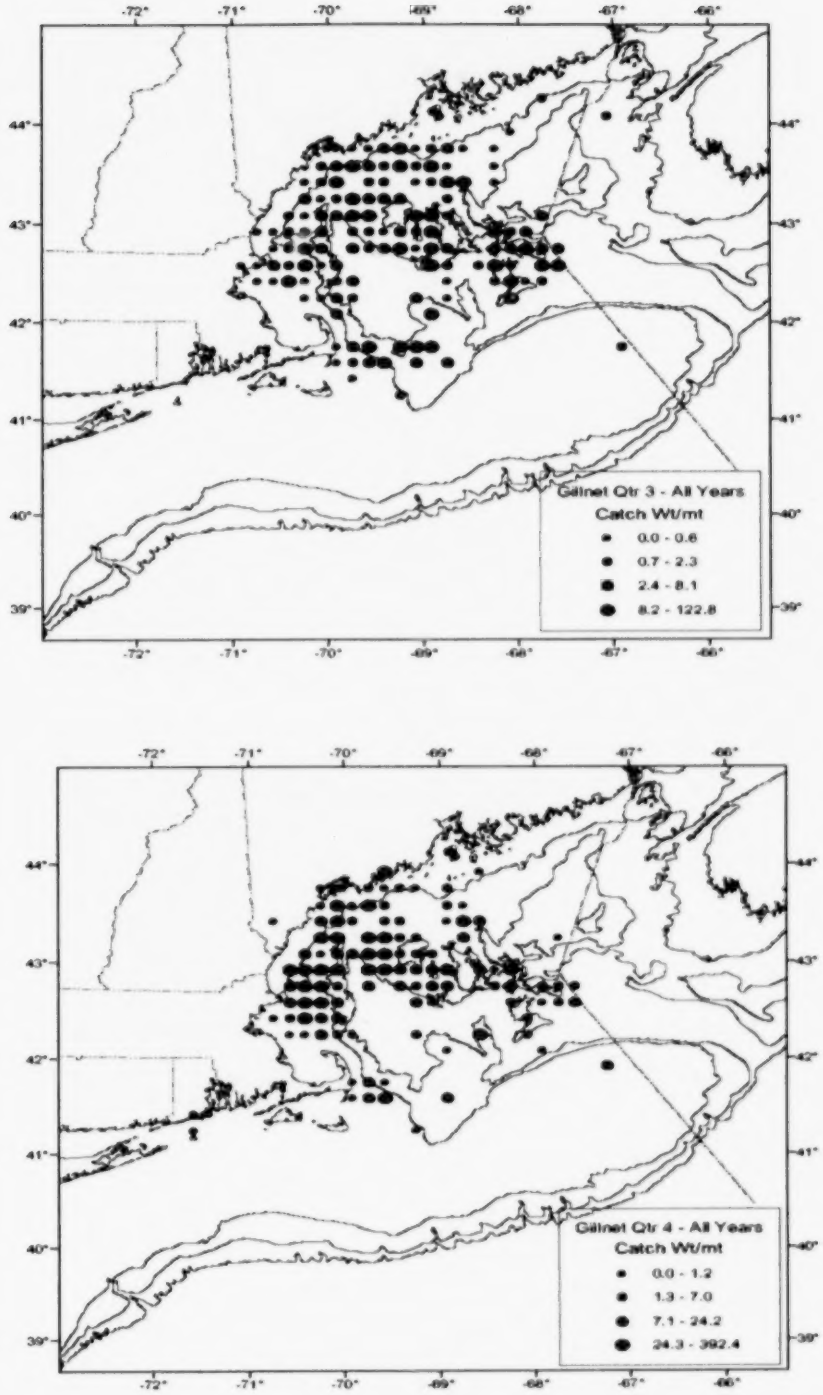


Fig. 9 (cont). Distribution of landings by the USA gillnet fleet 1982 to 1990, based on interview data aggregated on 10' squares.

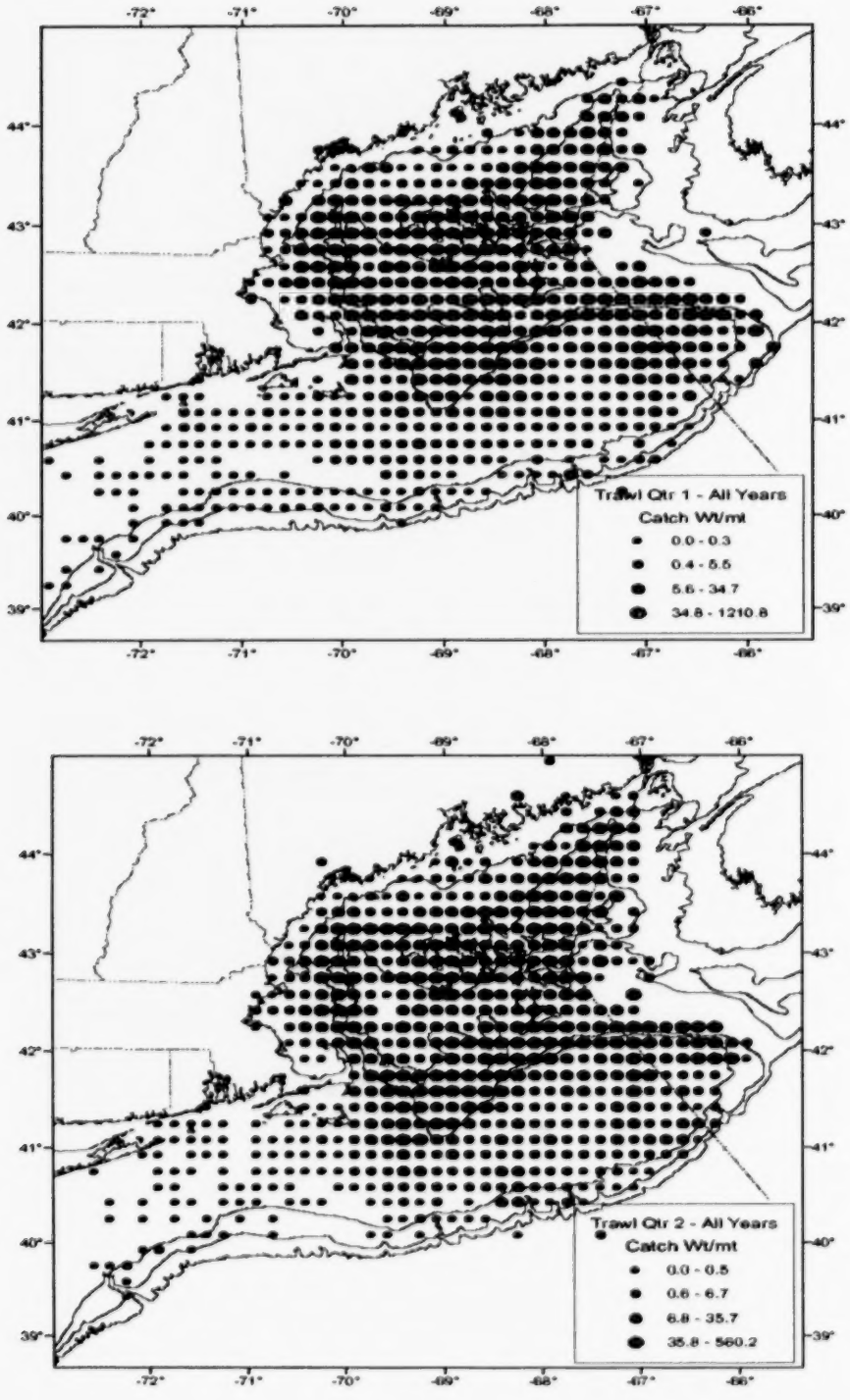
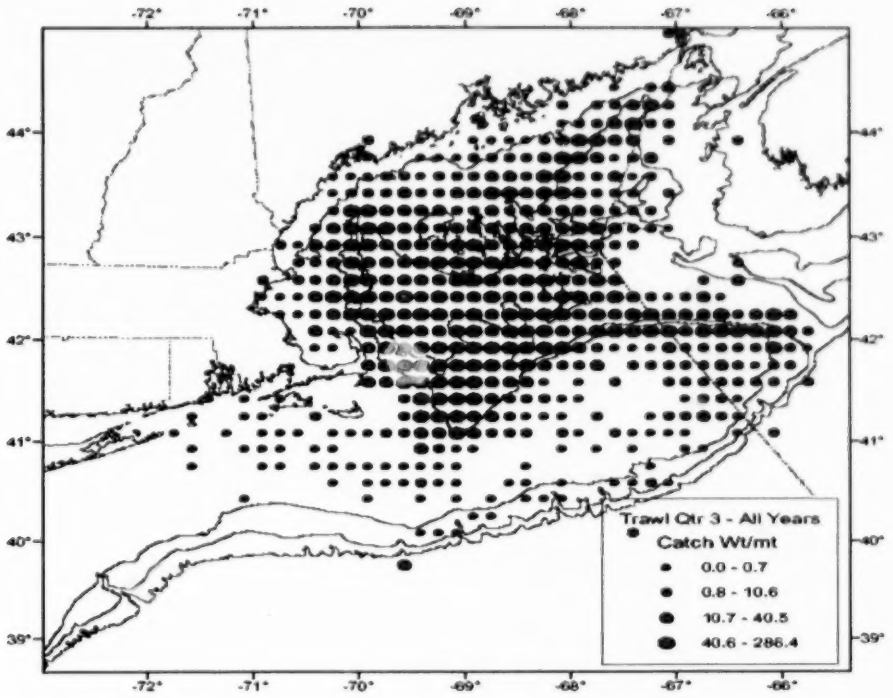


Fig. 10. Distribution of landings by the USA otter trawl fleet 1982 to 1990, based on interview data aggregated on 10' squares.



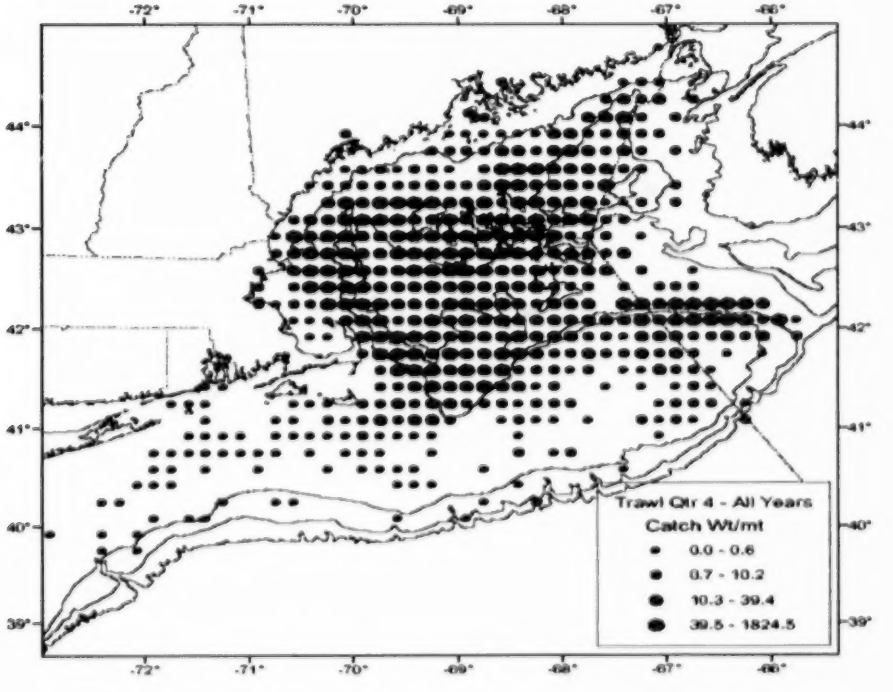


Fig. 10 (cont). Distribution of landings by the USA otter trawl fleet 1982 to 1990, based on interview data aggregated on 10' squares.

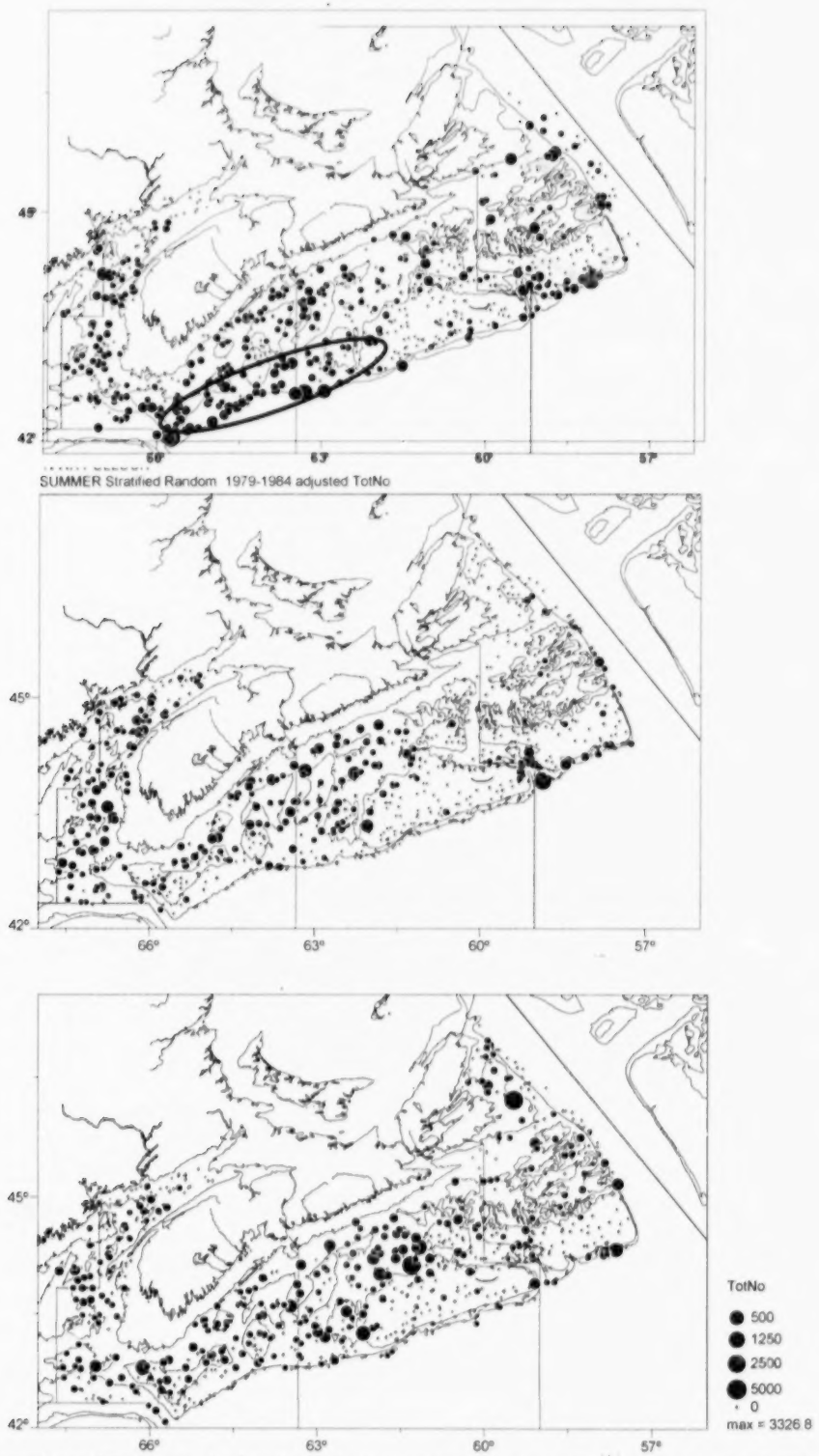


Fig. 11. Catches (numbers/30 min tow) of pollock during spring (top panel), summer and fall RV surveys, 1978-1984. The oval highlights a concentration along the edge noted in spring surveys, but not during the summer and autumn surveys.

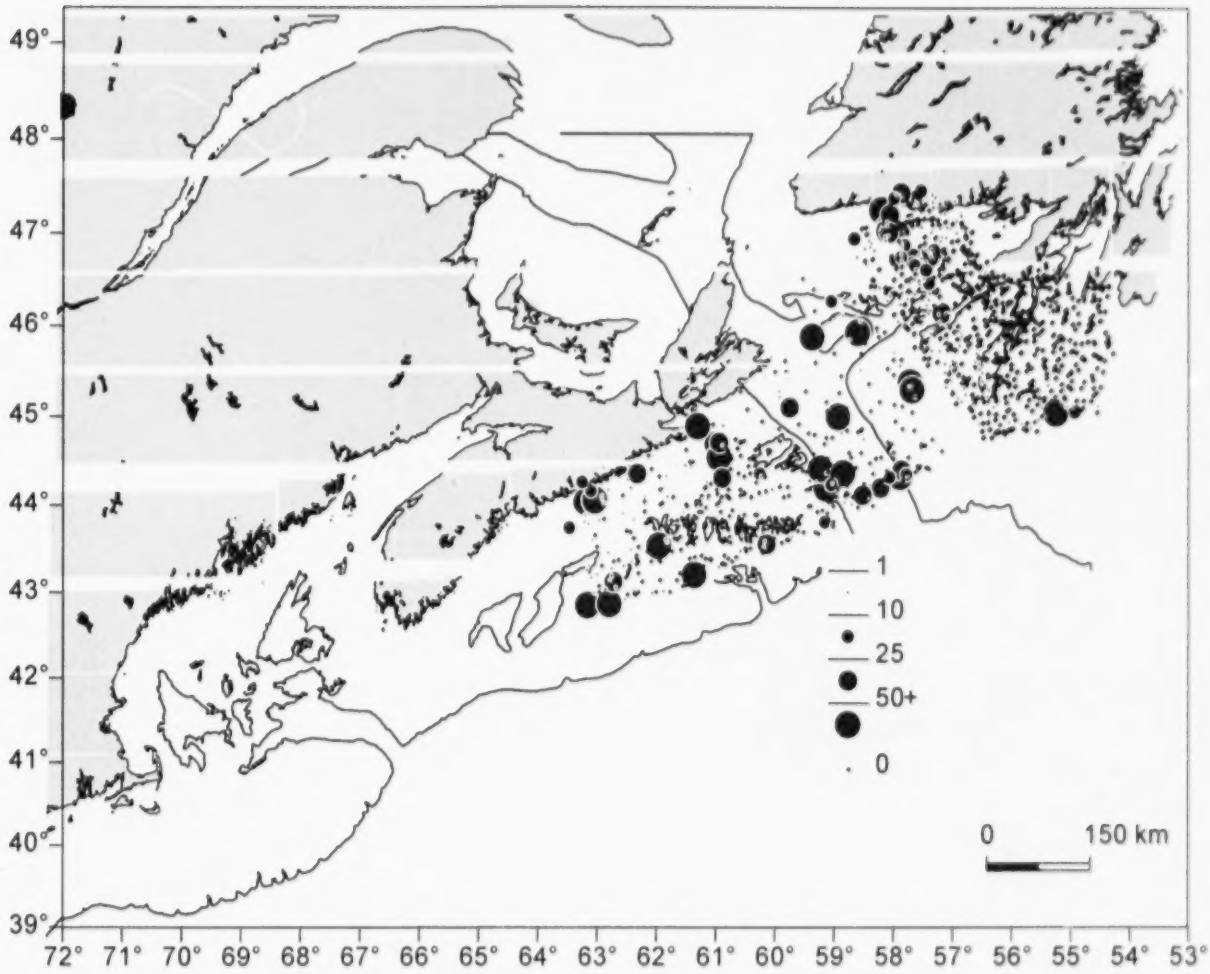


Fig. 12. Catches of pollock (#s/tow) for Scotian Shelf spring RV surveys 1978-1984 in 4VW and in 3Ps (1985-1990). Surveys used different nets, so the magnitude of the catches are not comparable. Null sets are indicated by the small '+'s.

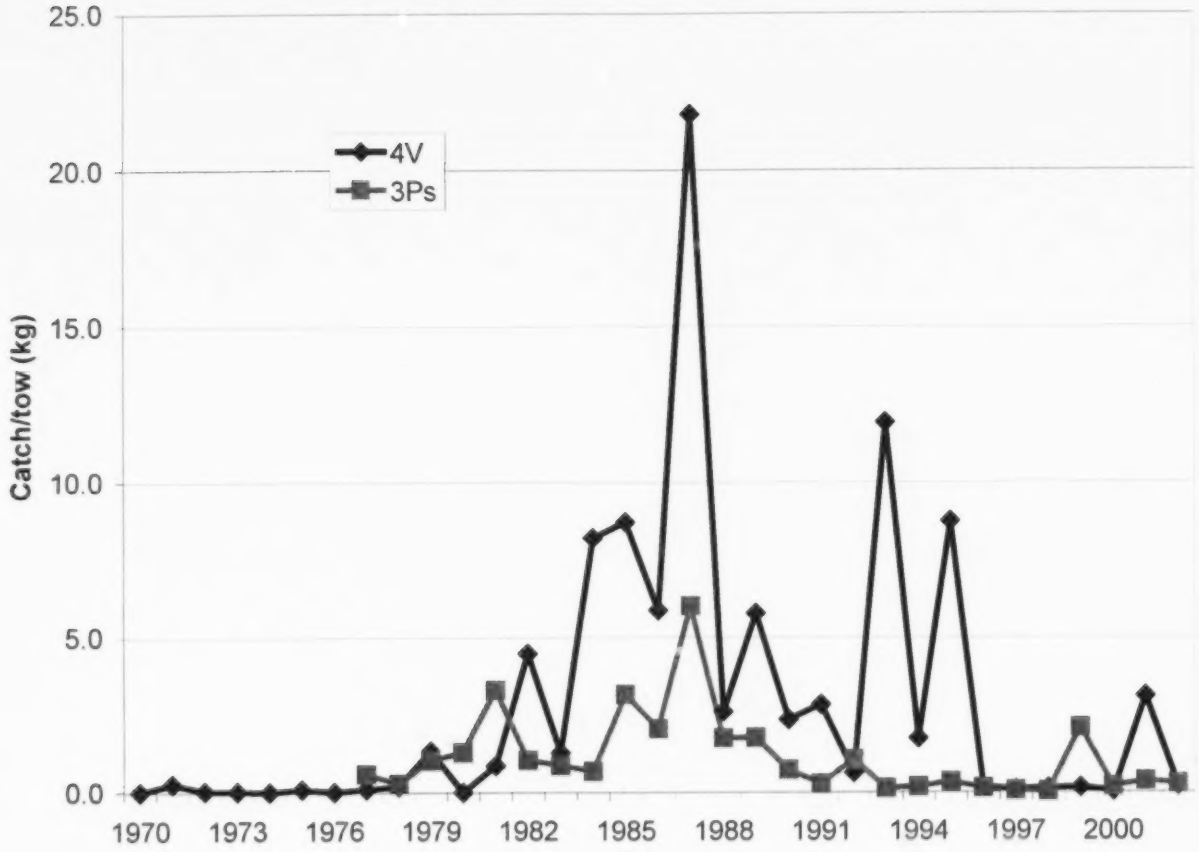


Fig. 13. Comparison of abundance indices (catch/tow) from southern Newfoundland (3Ps) and eastern Scotian Shelf surveys. The surveys employed different nets and vessels, and no conversions are available. Thus, the series should be compared for trend only.

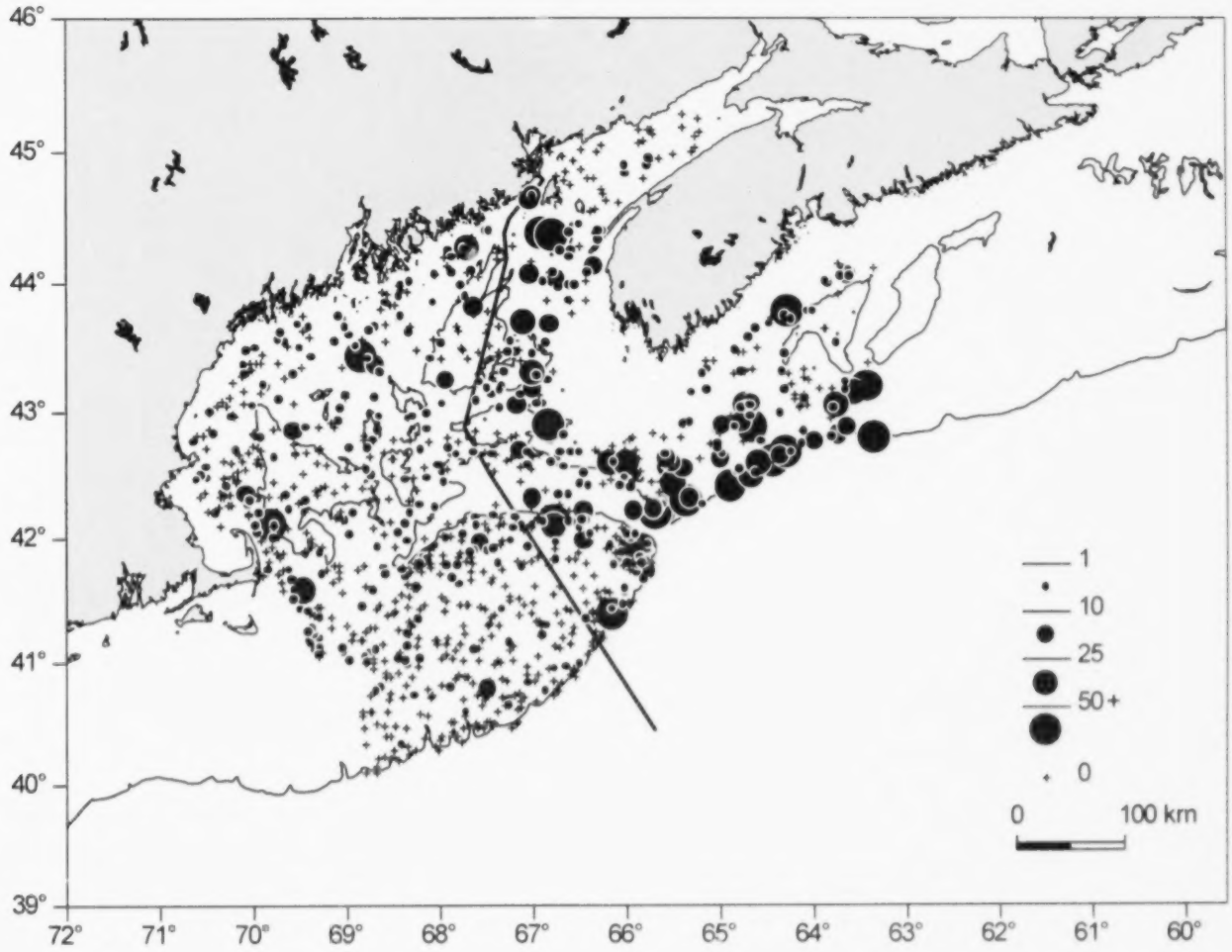


Fig. 14. Catches of pollock (#s/tow) for Scotian Shelf spring RV surveys 1979-1984 in 4X and USA surveys completed in the spring of the same years. The surveys used different nets, so the magnitude of the catches are not comparable. Null sets are indicated by the small '+'s.

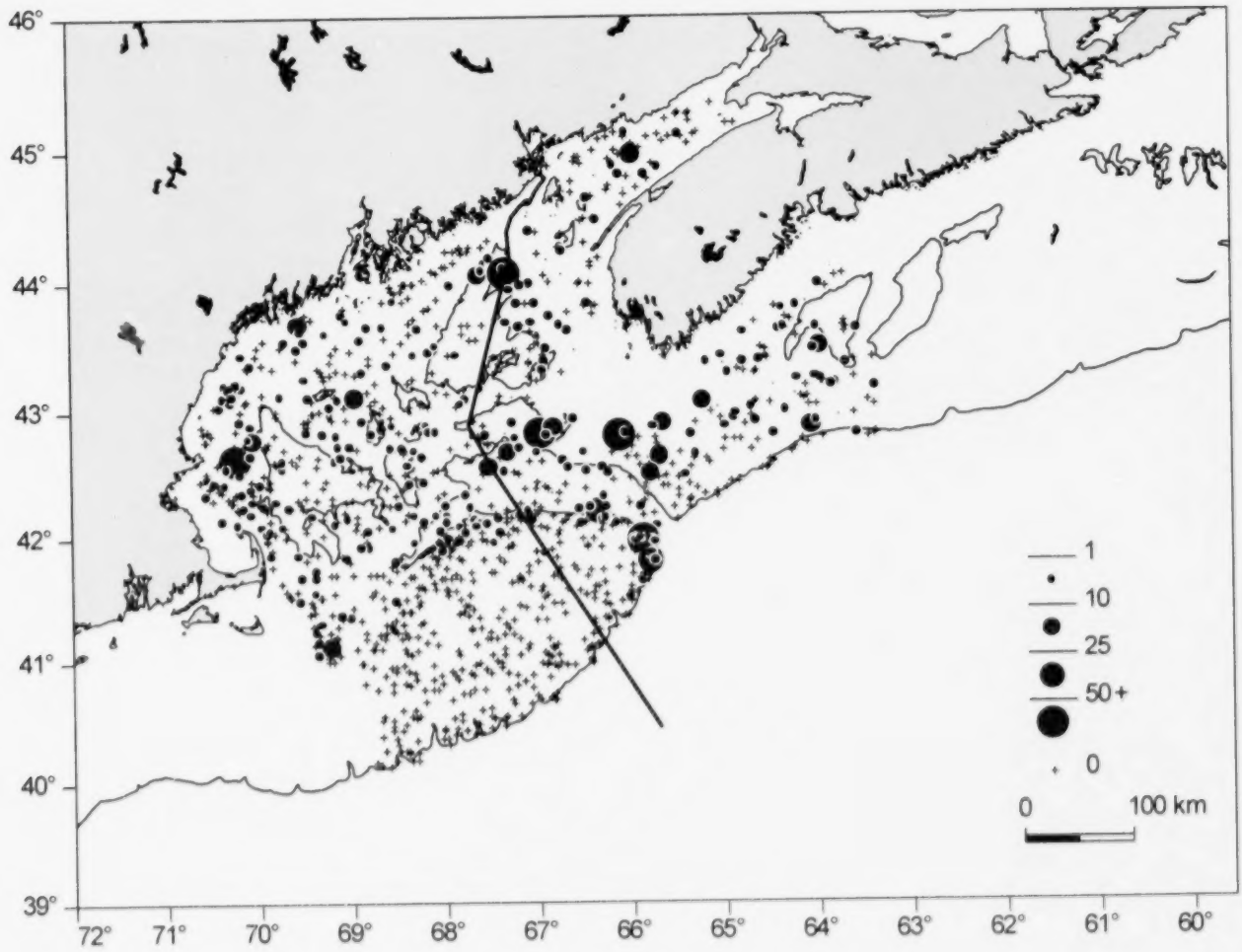


Fig. 15. Catches of pollock (#s/tow) for Scotian Shelf autumn RV surveys 1979-1984 in 4X and USA surveys completed in the autumn of the same years. The surveys used different nets, so the magnitude of the catches are not comparable. Null sets are indicated by the small '+'s.

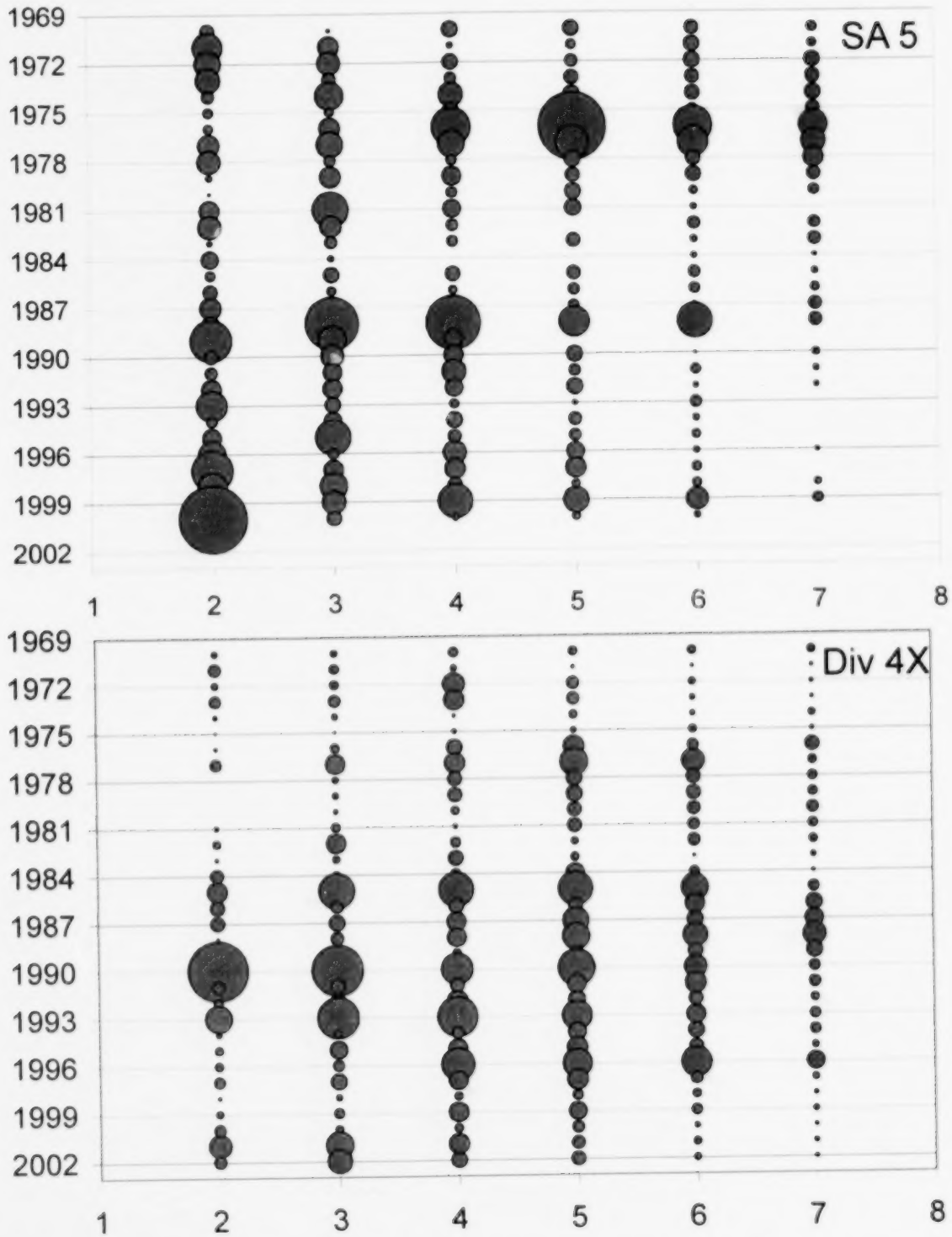


Fig. 16. Age specific indices of abundance for USA SA 5 surveys of pollock (1970-2000, autumn) compared with indices of abundance of pollock from Canadian surveys of pollock in NAFO Div. 4X (1970-2002, summer). The diameter of the "bubble" is proportional to the value of the abundance index at age.

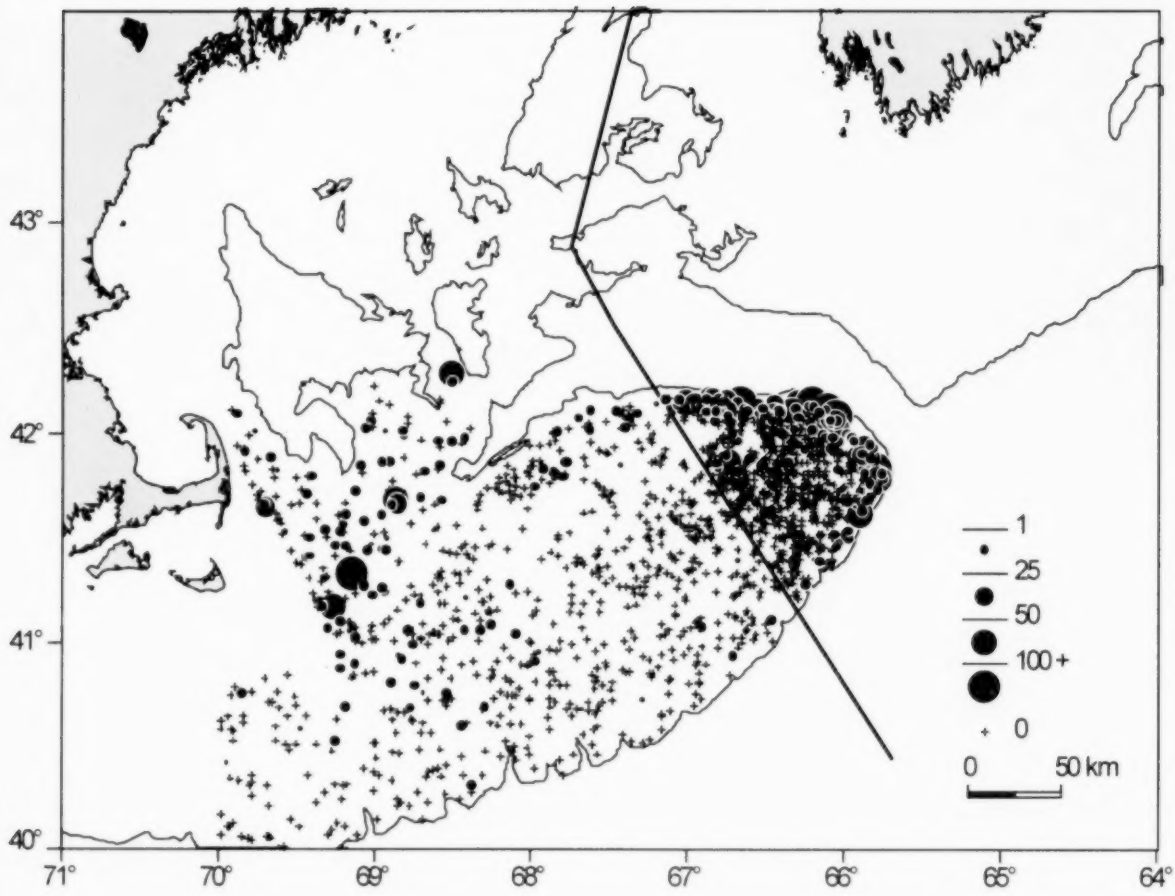


Fig. 17. Distribution of pollock catches during Canadian surveys on Georges Bank, 1986-2003.

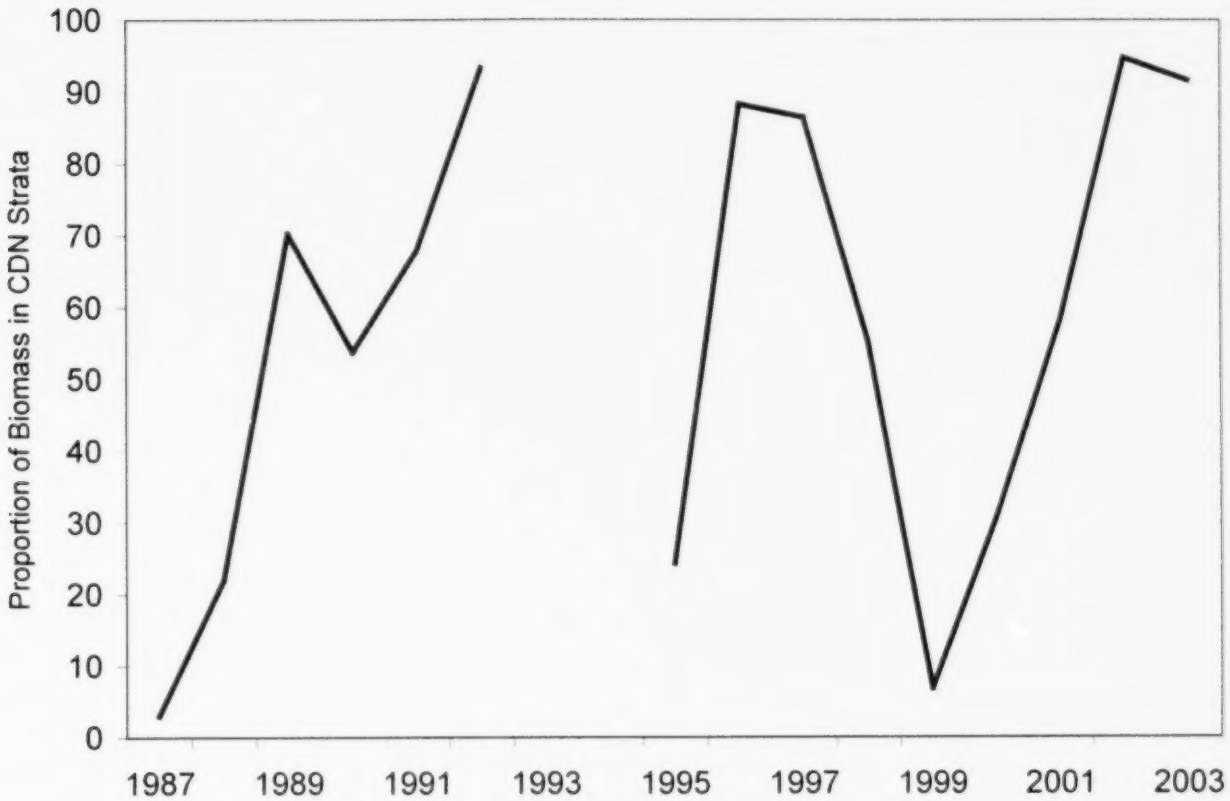


Fig. 18. Proportion of pollock biomass in Canadian waters during Canadian spring surveys of Georges Bank. The proportion was calculated as the ratio of biomass in Strata 1-2 to the total biomass in Strata 1-4 as used during the Canadian surveys.

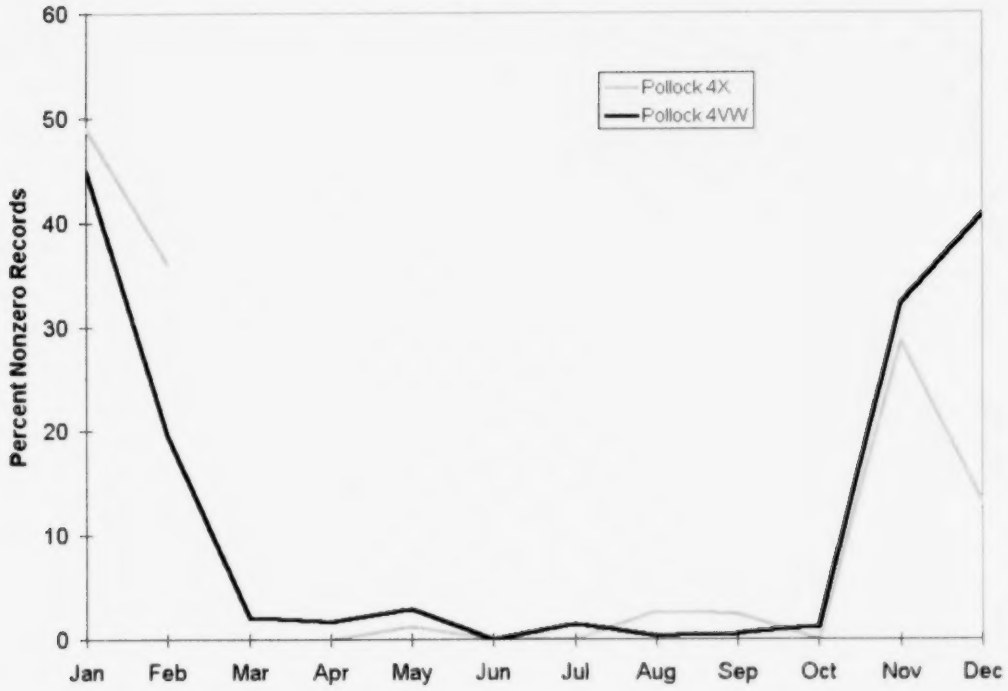


Fig. 19. Occurrence of pollock eggs in SSIP surveys conducted from 1978-1982, on the Scotian Shelf, disaggregated into eastern (4VW) and western (4X) components.

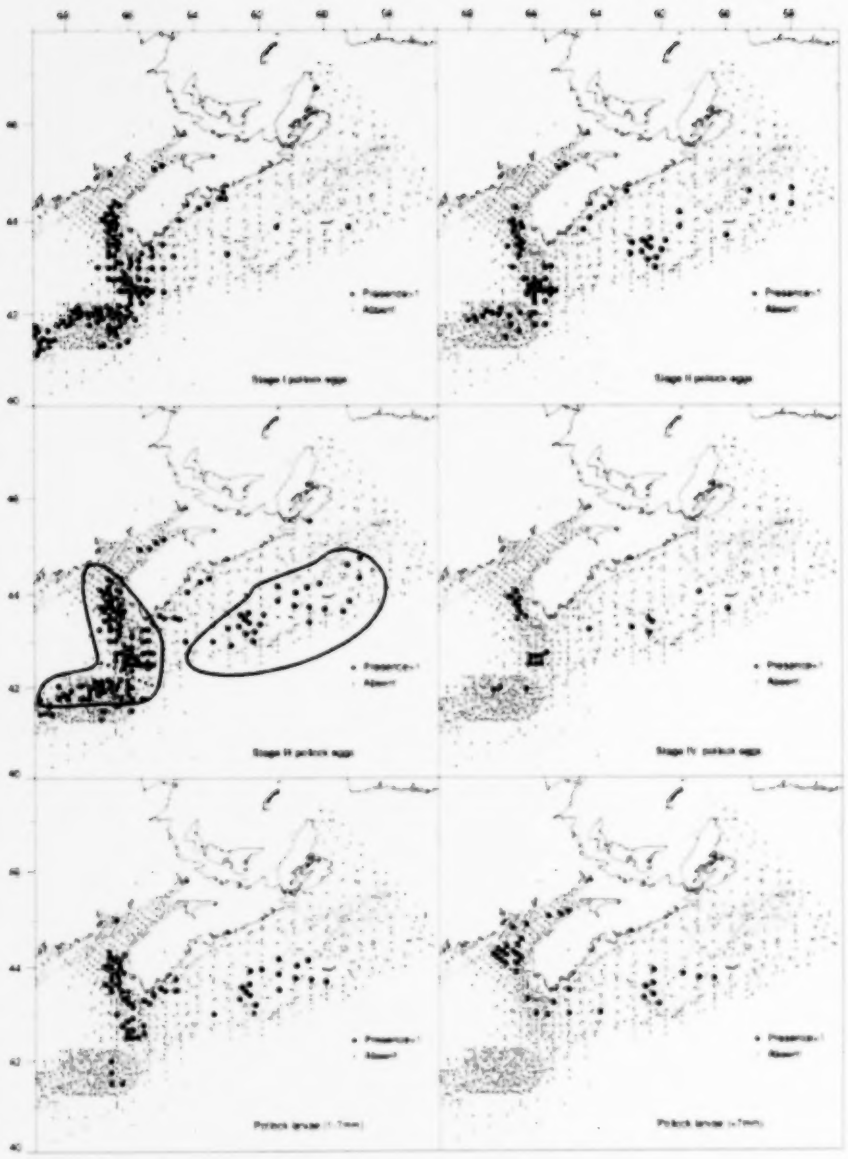


Fig. 20. Composite plots of all Canadian ichthyoplankton survey data for different life history stages of pollock, 1975-1997, shown as presence/absence at each station. Reproduced from Hanke et al. (2001). Areas of spatial continuity potentially corresponding with stocks are highlighted in the middle left panel.

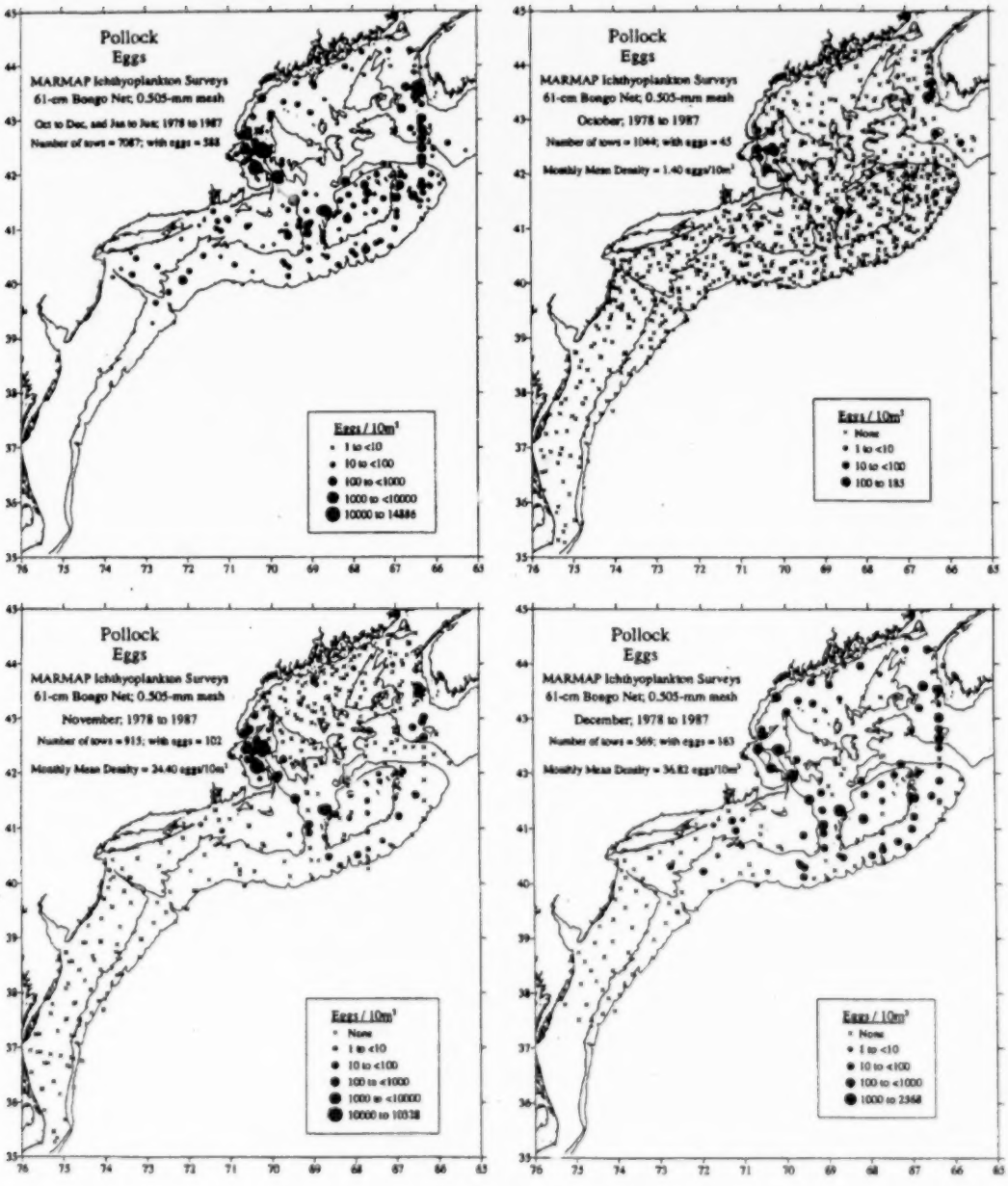


Fig. 21. Distribution of pollock eggs collected during NEFSC MARMAP offshore ichthyoplankton surveys. The top left panel shows data from Oct to Dec, and Jan to June, 1978 to 1987, and the remaining panels show monthly distributions over the same years. Egg densities are represented by dot size. Reproduced with permission from Cargnelli et al. (1999).

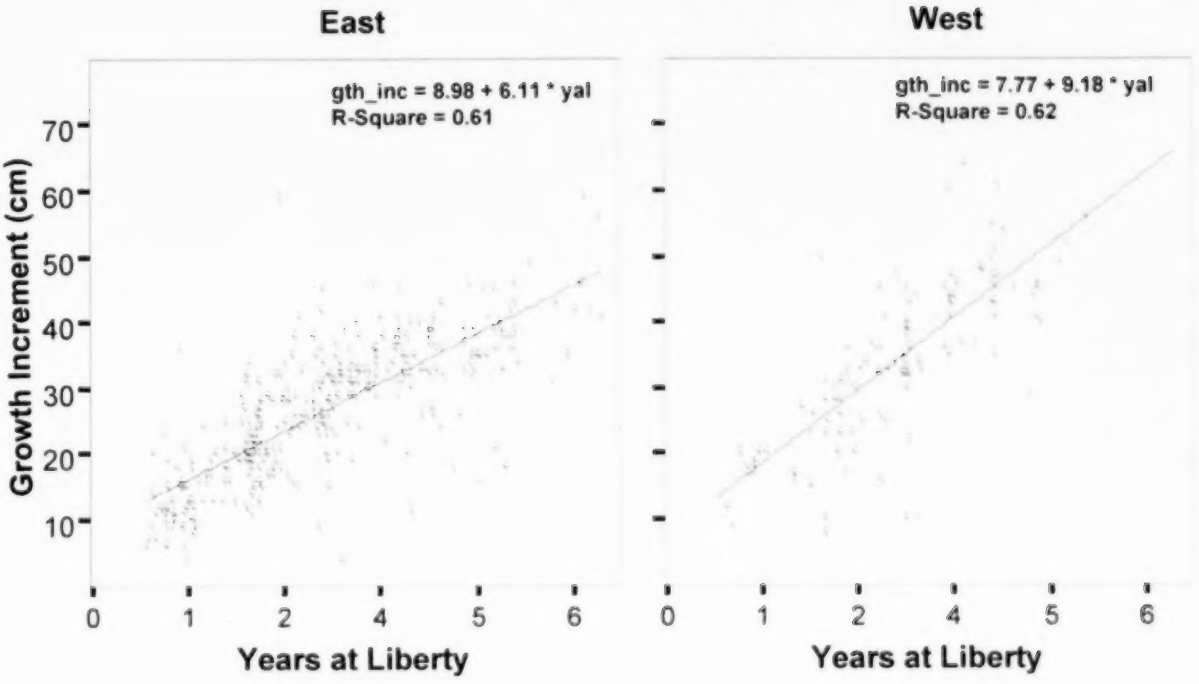


Fig. 22. Regressions of the increments of growth (cm) observed in marked pollock over a known period, compared for those released in the eastern and western portion of the management unit. The fish included in the regressions were those assumed to be age 2 upon release (from Neilson et al. 2003).

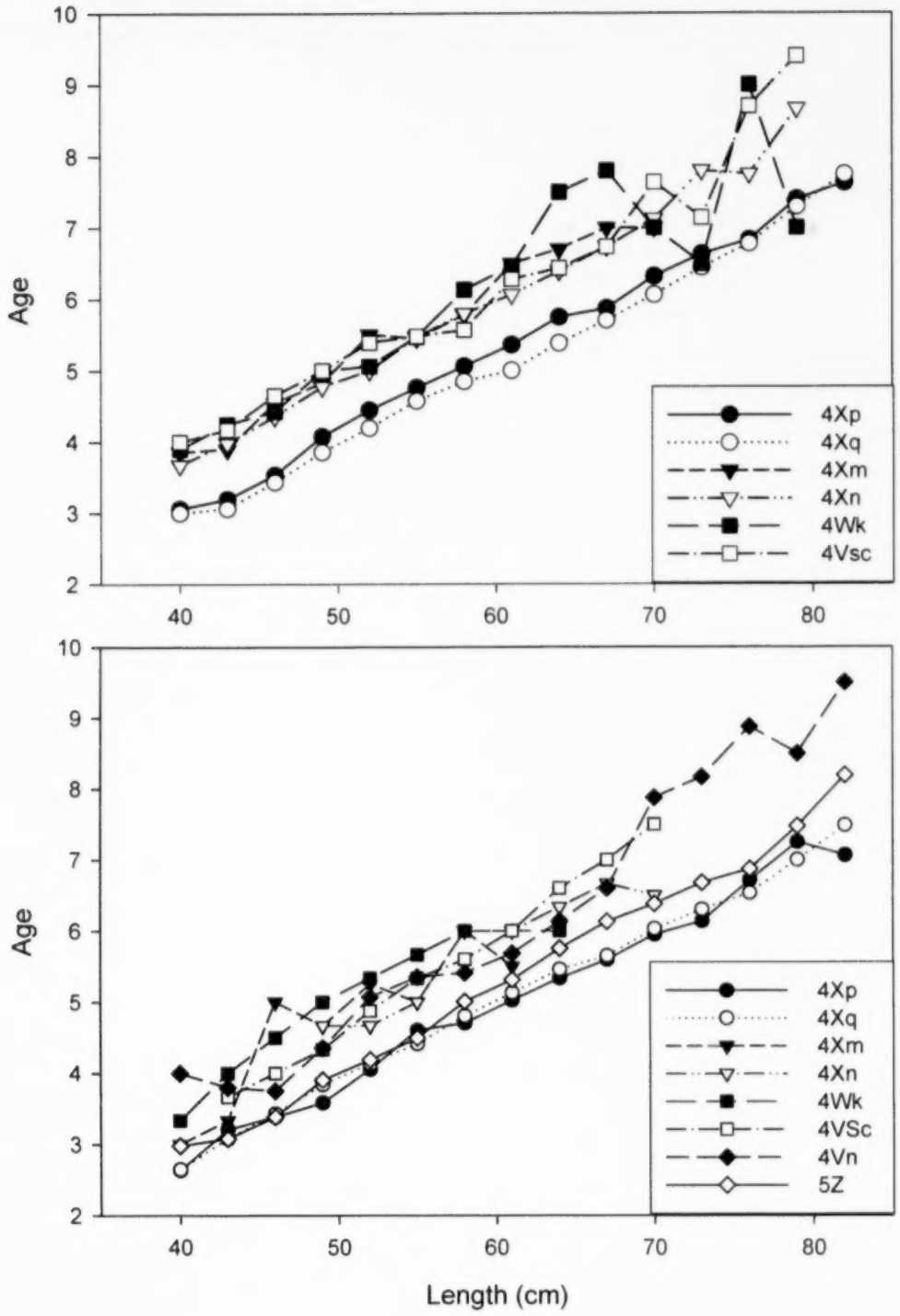


Fig. 23. Mean age at length for pollock by unit area (1995-2002) during February to May (top) and June to August (bottom) in the commercial fishery.

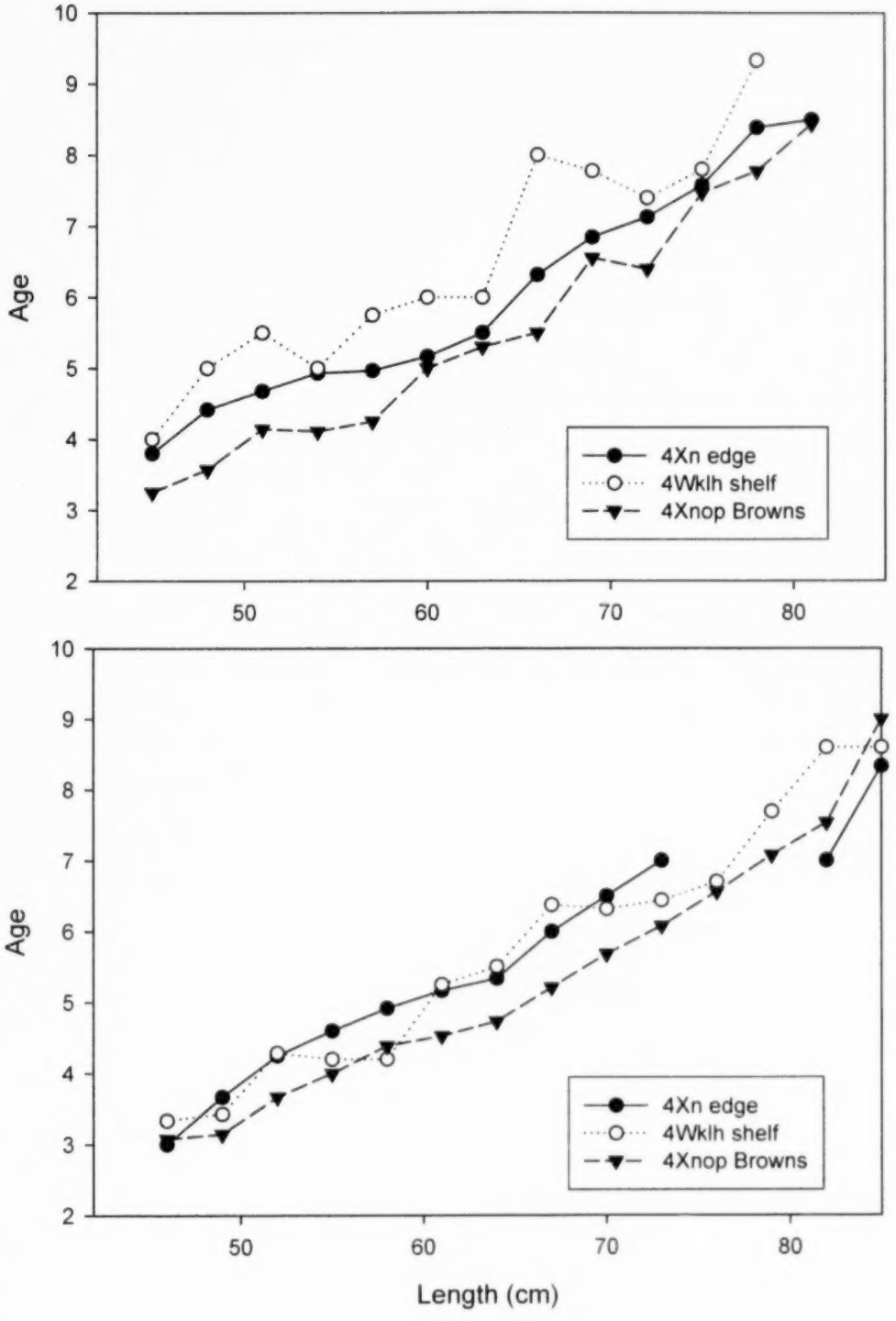


Fig. 24. Mean age at length for pollock from spring (top) and summer (bottom) surveys (1978-1984) compared by geographic region.

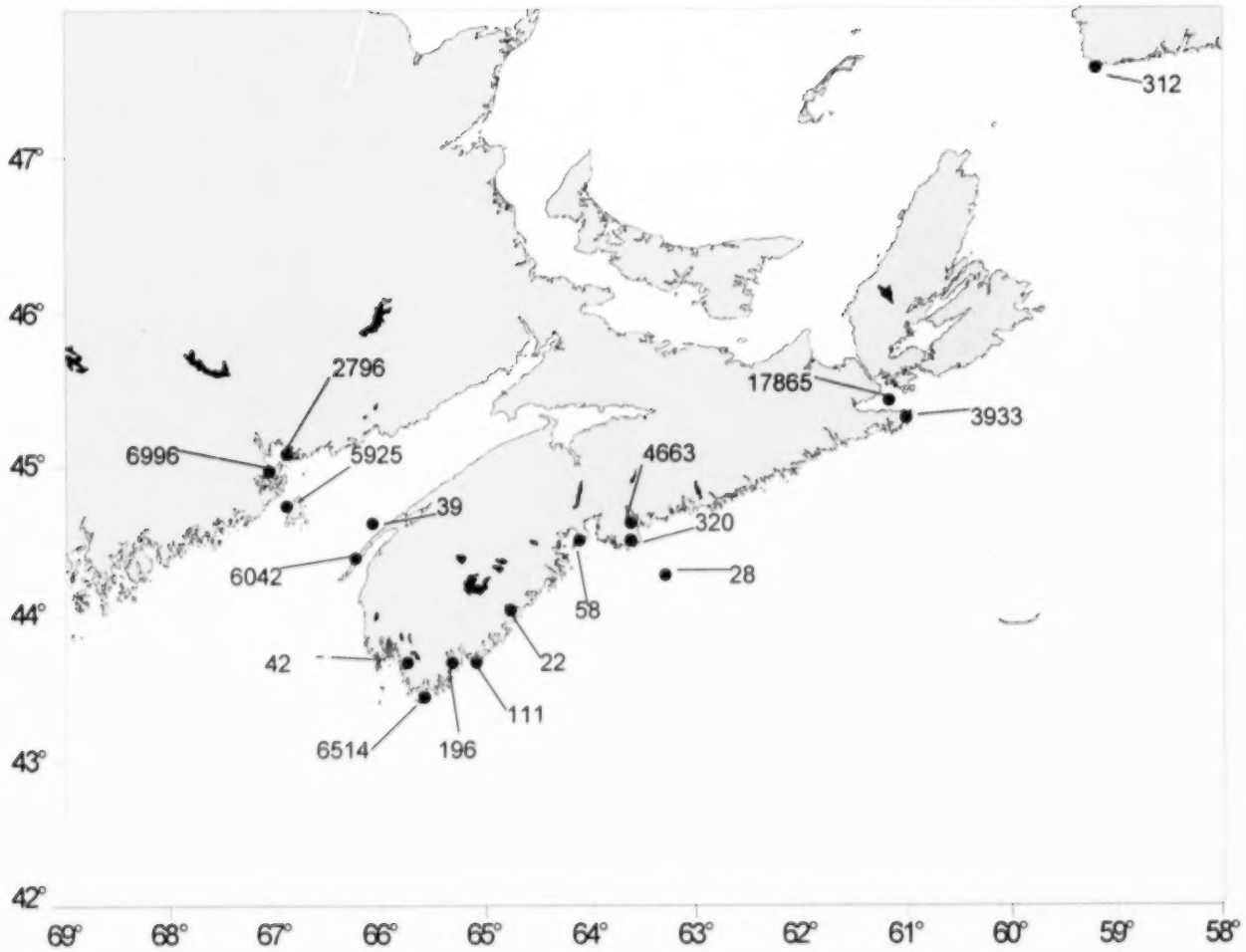


Fig. 25. Map of the pollock mark-recapture area, showing the sites of release and the numbers of marked pollock released at each site between 1978 and 1985.

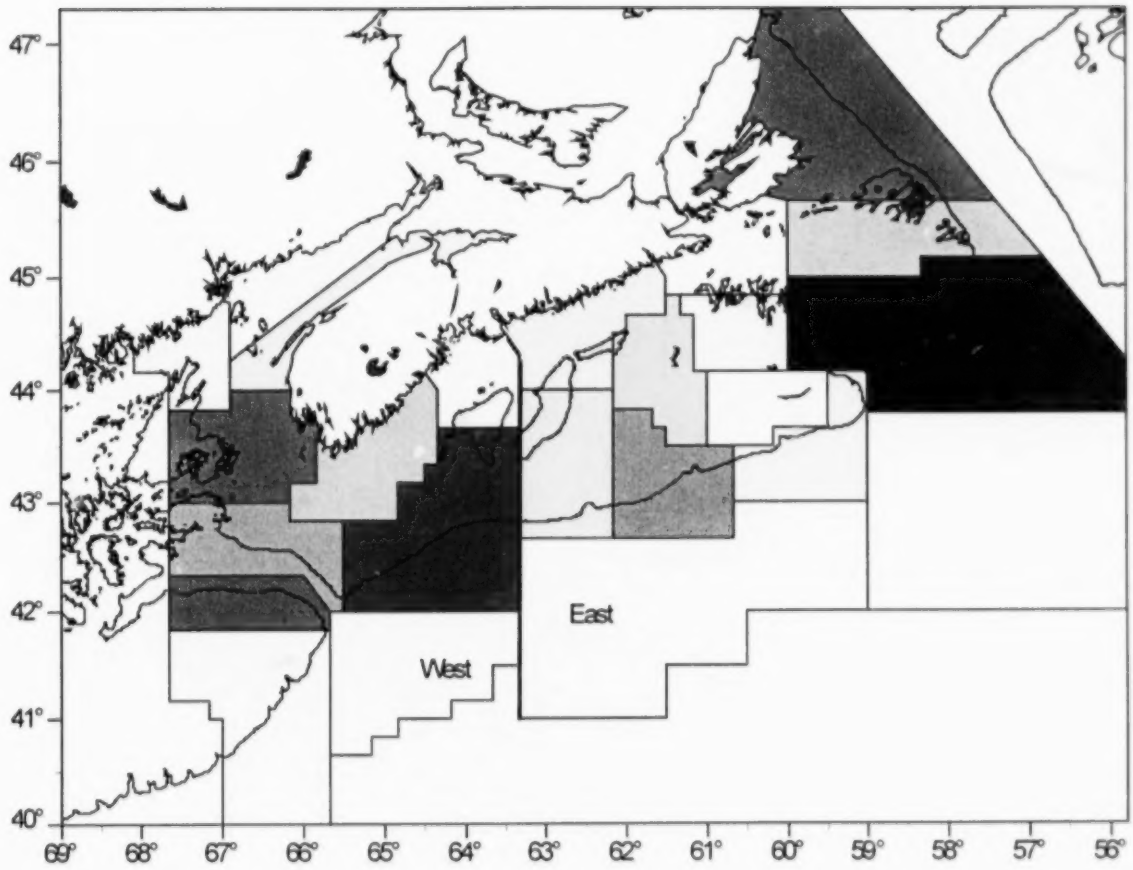


Fig. 26. The distribution of standardized mobile gear fishing effort for pollock among statistical Unit Areas between 1979 and 1990, the period of recaptures of marked pollock on the Scotian Shelf. The proportional effort is linearly scaled to the degree of shading in each Unit Area, with darker areas denoting higher levels of effort.

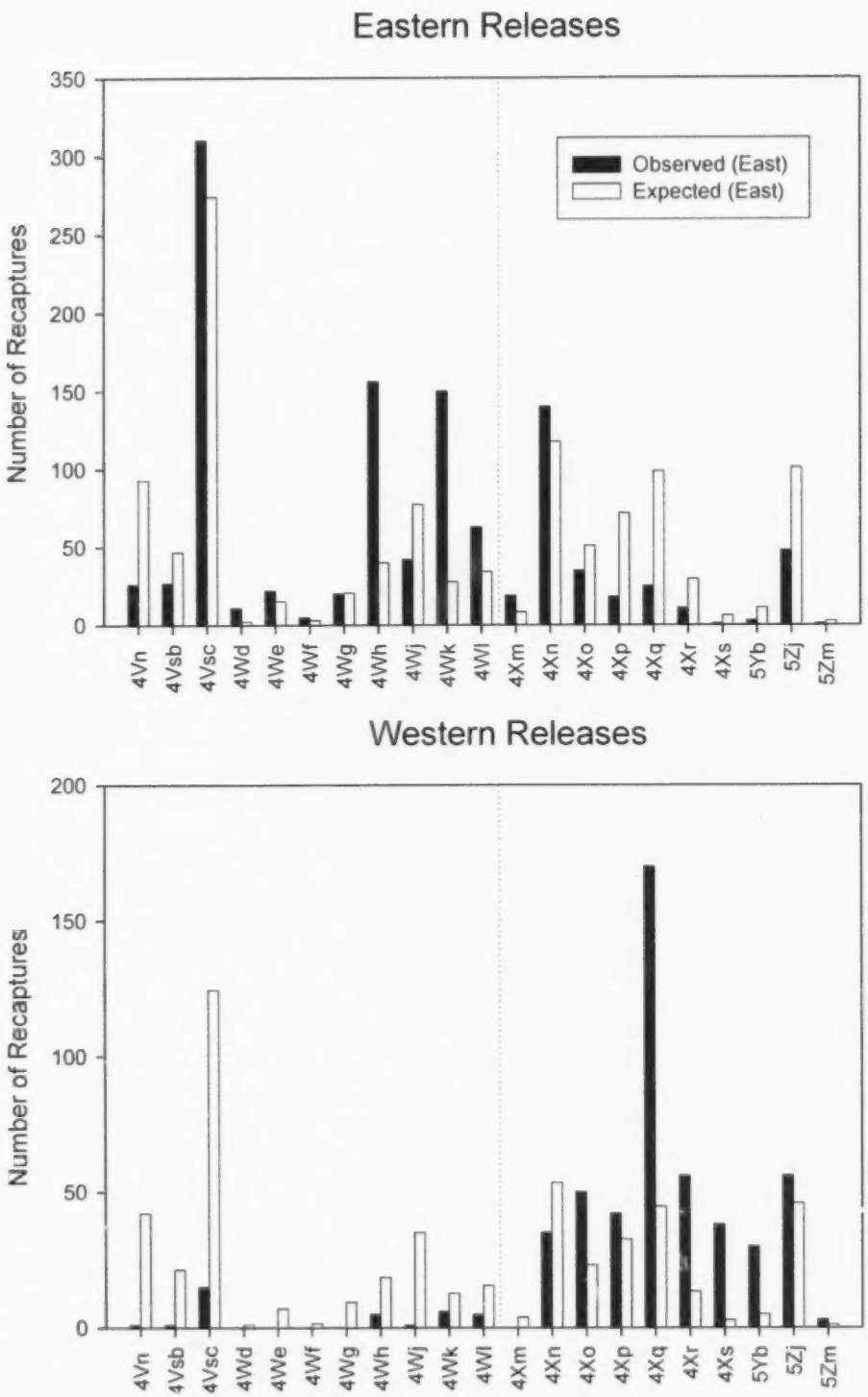


Fig. 27. The distribution of observed and expected recaptures of pollock by the mobile gear fishery by Unit Area for fish released on the eastern and western halves of the management unit. The expected recaptures are based on a pro-rata distribution of the total number of mobile gear recaptures given the fishing effort shown in Figure 21. The dashed line highlights the boundary between Divs 4VW and 4X within the current management unit.

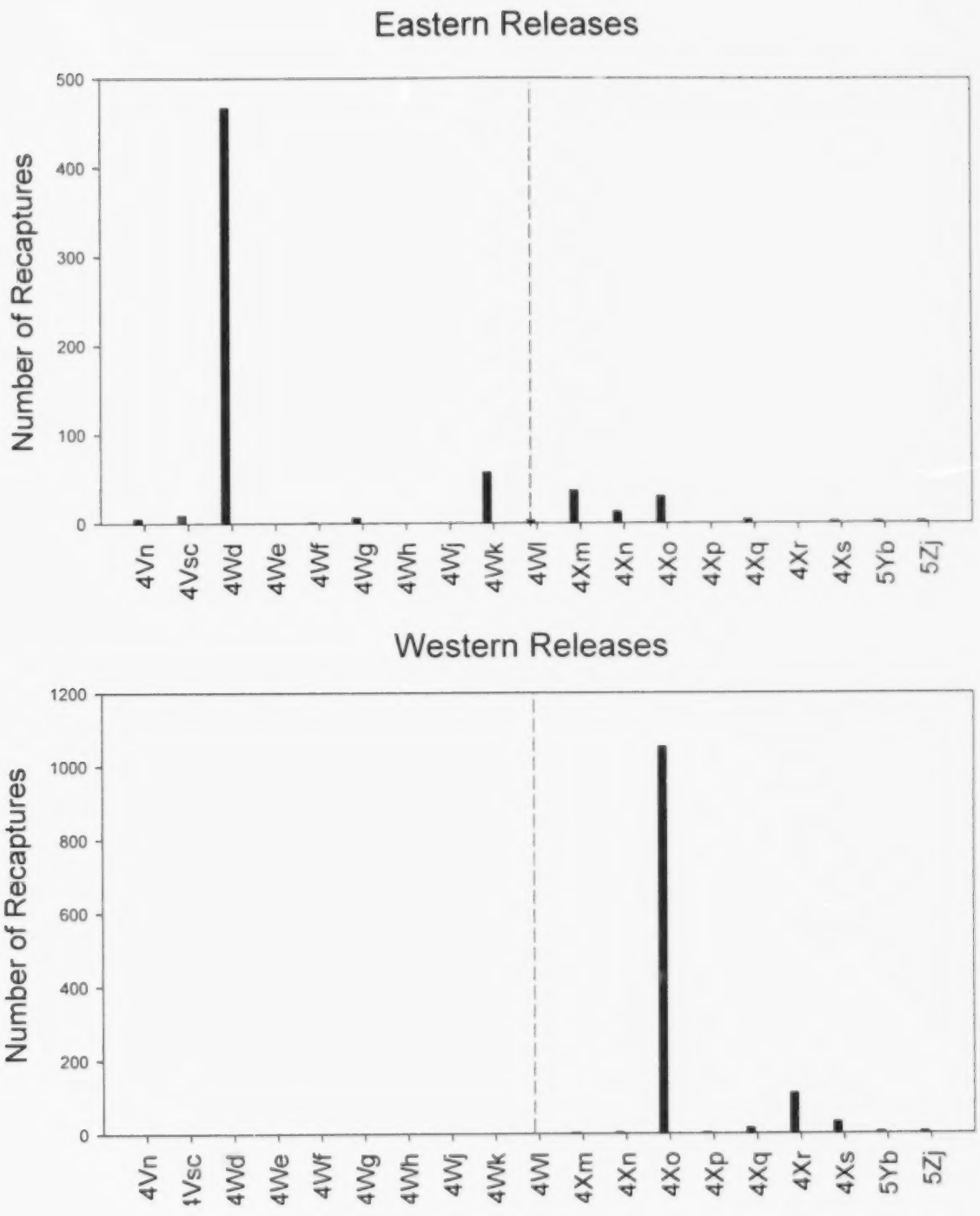


Fig. 28. The distribution of observed recaptures of pollock by the fixed gear fishery by Unit Area for fish released on the eastern and western halves of the management unit. The dashed line highlights the boundary between Divs 4VW and 4X within the current management unit.

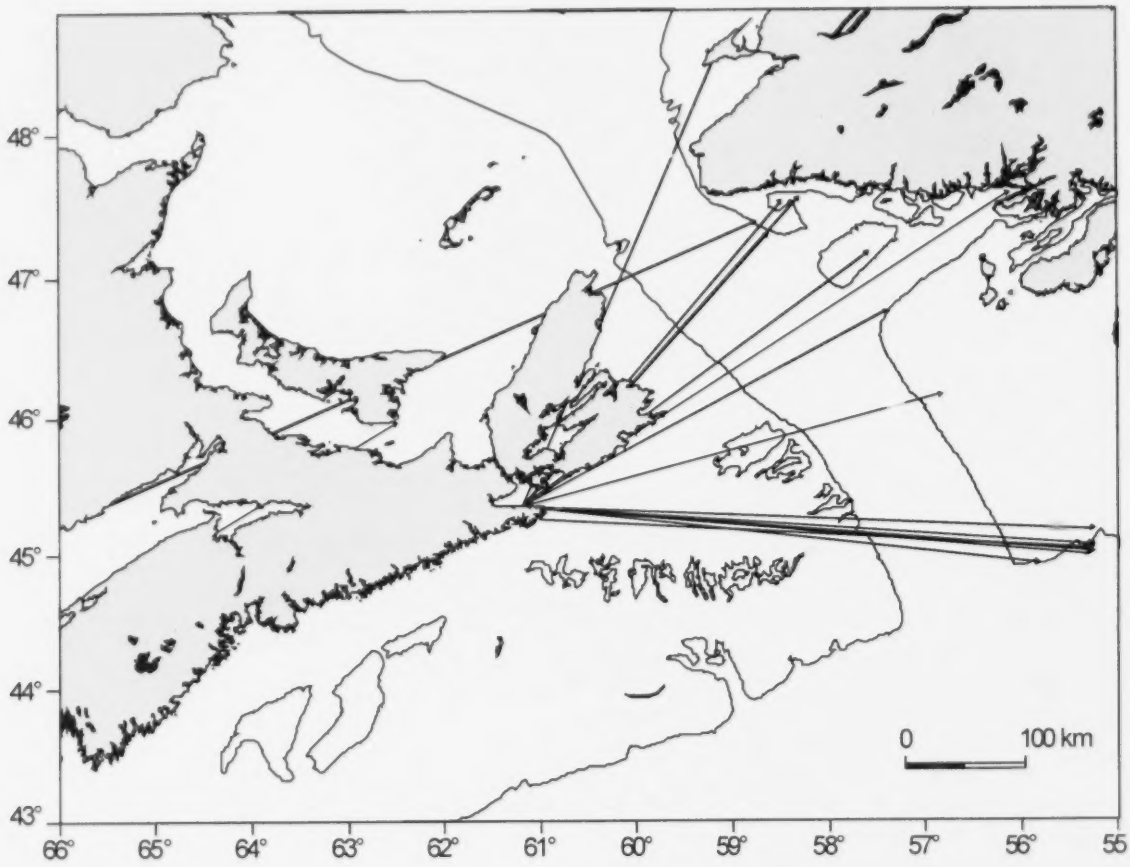


Fig. 29. Locations of pollock tagged within the management unit and recaptured outside the northern limit of the management unit, where coordinates of recapture were known. In addition, 20 recaptures reported from northern Newfoundland and Labrador were excluded, as there were insufficient supporting data to validate the returns.

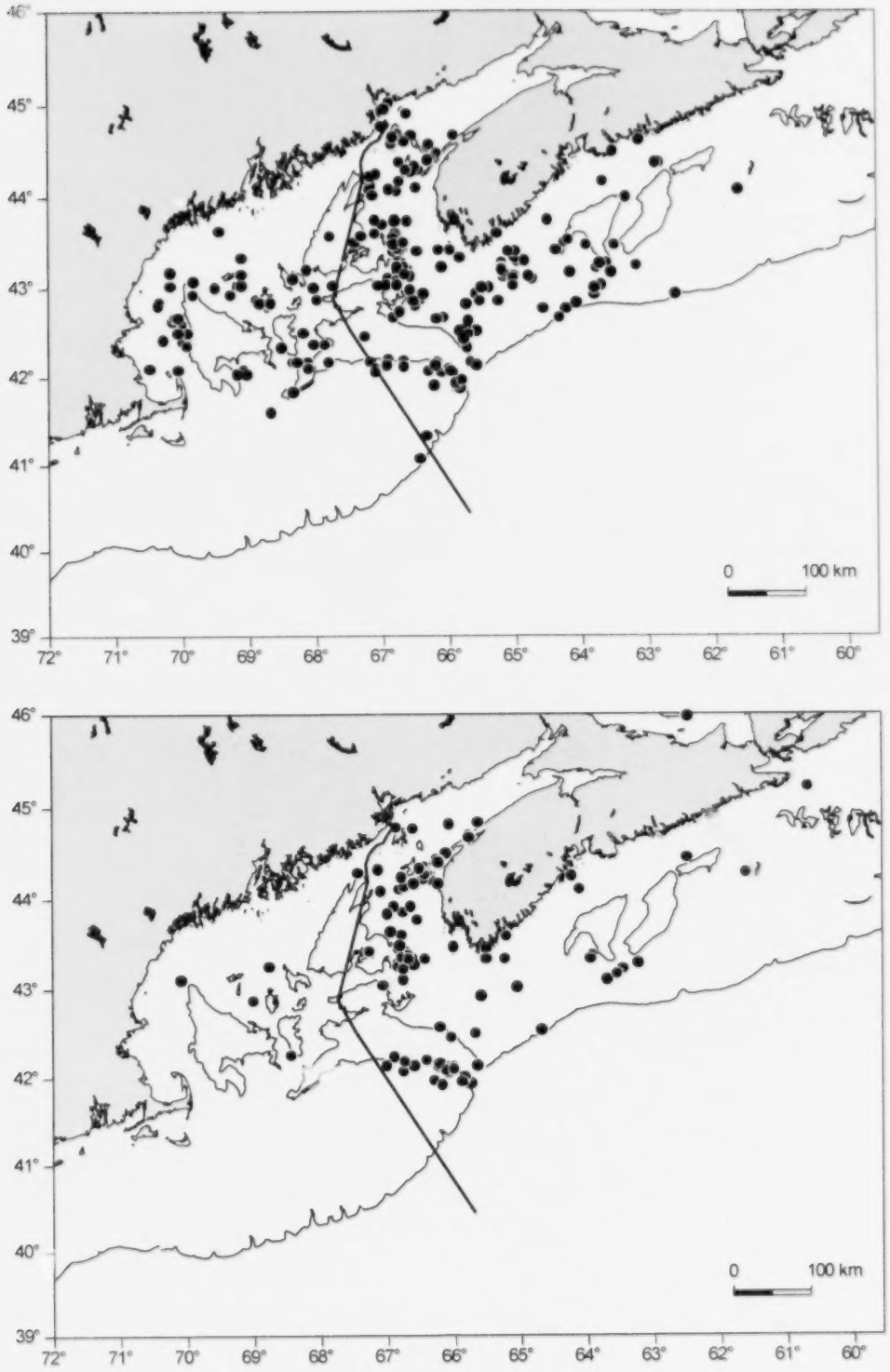


Fig. 30. The location of recaptures of marked pollock released on the western side of the Bay of Fundy (statistical Unit Area 4Xs, top panel) and the location of recaptured marked pollock released on the eastern side of the Bay of Fundy (statistical Unit Area 4Xr, bottom panel).

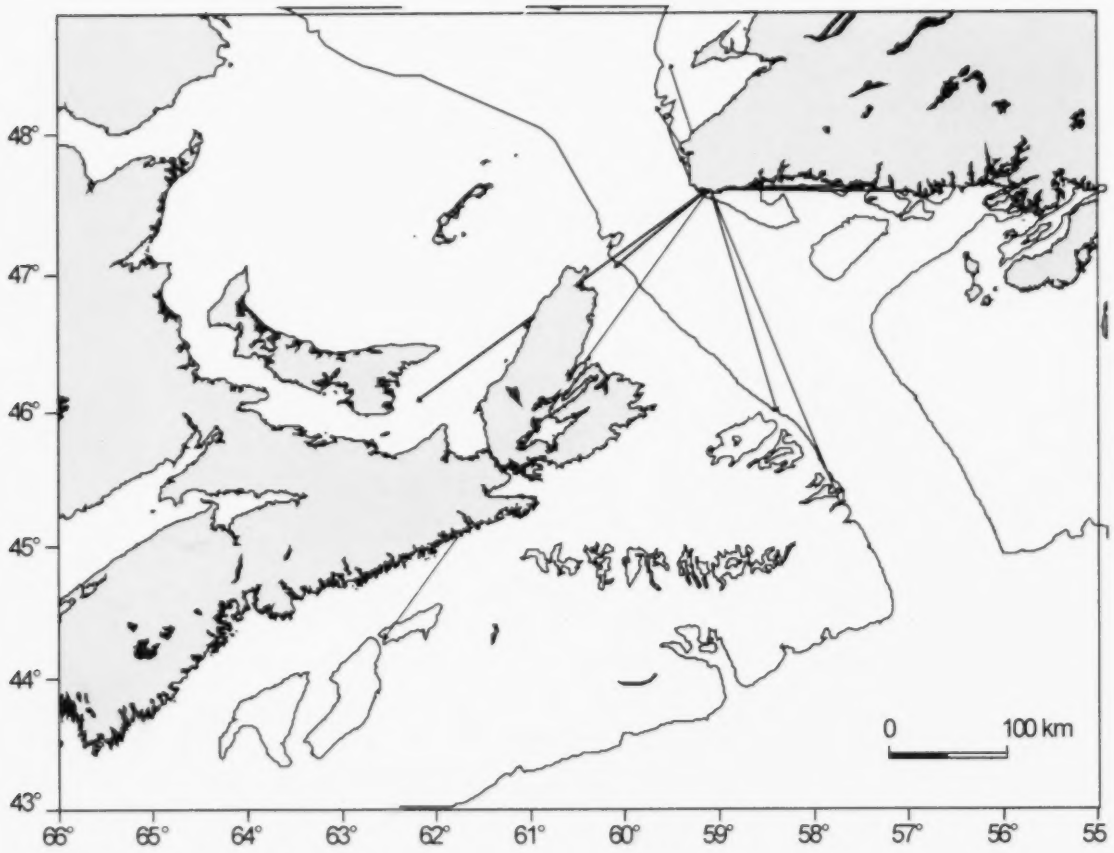


Fig. 31. The location of recaptures of marked pollock released off southwestern Newfoundland, where coordinates of recapture were known. The total recaptures were 16, with some recaptures close to the point of release not obvious on the figure.